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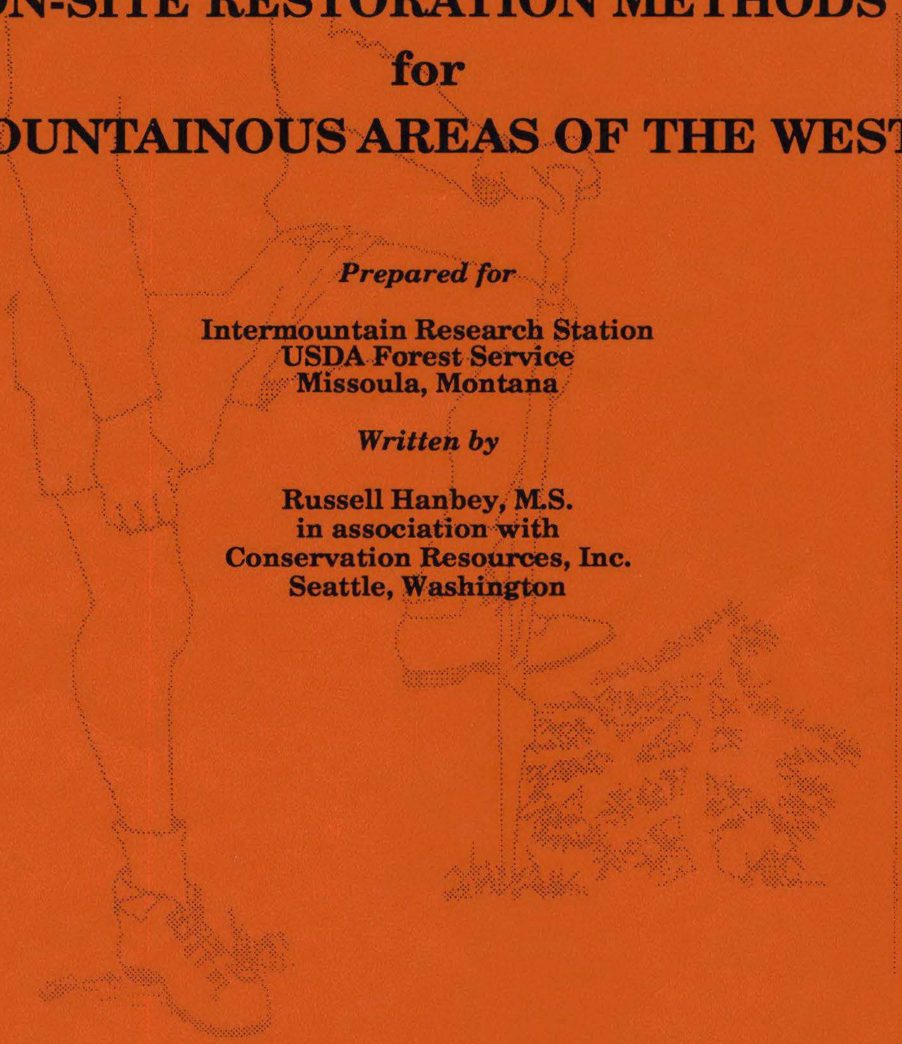
ON-SITE RESTORATION METHODS
for
MOUNTAINOUS AREAS OF THE WEST

Prepared for

Intermountain Research Station
USDA Forest Service
Missoula, Montana

Written by

Russell Hanbey, M.S.
in association with
Conservation Resources, Inc.
Seattle, Washington



The reference to "an earlier chapter" on page 11, last line of the first full paragraph, is in error. There is a companion book about to be published entitled The Restoration of Disturbed Sites in America: Regional Techniques for the Practitioner (working title) which includes a discussion by David Cole on Impact Management. For more information on this book, contact The Student Conservation Association, Inc. Att. Destry Jarvis, P.O. Box 550, Charlestown, NH 03603.

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1.0 INTRODUCTION

Restoration ecology is an emerging science that is redefining our relationship with the land. Concerned citizens, educators, scientists and land managers are responding to a need to reassess our role as caretakers of both public and private lands. Our natural landscapes are now being viewed as more than preserves for recreation, resource extraction and research. Two hundred years of landscape abuse has forced our hand in the way we manage our national heritage of natural resources. Environmental restoration is one operative approach designed to restore our disturbed lands to a predisrupted state.

This publication is an initial attempt to give the restorationist concepts, tools, techniques and examples of how to restore damaged lands in remote and mountainous areas of Western North America. The emphasis in this text is "on-site" approaches. On-site approaches are those that rely on localized resources to prepare, vegetate and manage a site. The systems presented are holistic and integrated with each other. The inherent seclusion of sites that are referred to requires the practitioner to utilize existing resources. Extreme weather, limited field season, site sensitivity, genetic integrity and logistical challenges all contribute to a decision to rely on subtle on-site practices over massive relandscaping and introduction of nonnative soils, soil amendments and plant species.

Traditional horticultural and landscaping practices are recognized in this text as generalizable to backcountry work. Proper site preparation and soil management precede any successful rehabilitation on exceptionally impacted terrain. Transplanting, root division, root pruning and layering are propagation techniques that are common to the nursery trade and have been shown to be successful in remote site restoration. Seed beds, mulching, irrigation, composting, plant salvage, soil solarization, selective pruning and naturalized landscaping are newer techniques that offer tremendous potential in remote site restoration. Introduced in this text are the SITE RESTORATION WORKSHEET and the THREE-YEAR RESTORATION PLAN. These were developed to give the practitioner a framework for systematically organizing a restoration project in geographically challenging areas.

Restoration, also called revegetation, rehabilitation and reclamation, is very young as a land management practice in the mountainous regions of the West. Some projects, such as Cascade Pass in the North Cascades National Park, are approaching 25 years of implementation, but this is quite young when compared to traditional forest, fire, water, wildlife and range management practices over the decades. It does imply that a long term commitment is needed in order to carry a remote site restoration project to closure or maintenance level. The SITE RESTORATION WORKSHEET is structured on a three-year schedule. This should be considered the establishment phase where the bulk of on-site work will be done and will determine the ultimate success or failure of a project.

The Case Studies that are included are successful projects from a variety of montane and alpine sites. They represent different elevations, aspects, available rainfall, remoteness and agency or volunteer approaches. The Lost Lake project (Slagle/Wilson) represents a middle elevation project that utilized some heavy equipment and off-site nursery propagation support. Off-site support in the form of greenhouse propagation programs is not covered but is recognized as an important component in the provision of large volumes of plant material for selected projects. Several addenda are included that offer suggestions for organizing and equipping backcountry restoration activities. These can be blended with the SITE RESTORATION WORKSHEET and THREE-YEAR PLAN to project costs, labor and other management planning needs.

The value in allocating resources, time and energy toward repairing natural areas cannot be overlooked as an inherently worthy endeavor. This publication is being offered as a guide for those wishing to invest themselves in the process and the belief that we can rebuild what we have destroyed and redefine our relationship with the land that sustains us.

My thanks to my wife, Jeanne, who nurtured me through this effort; my typist Jan Sage, who formalized my words; Dave Cole, who envisioned this project; to Carroll Vogel, who set the stage; and Karen Mikolasy, who tidied up my text.

2.0 NATURAL LANDSCAPE CONSIDERATIONS, SITE DESIGN AND PLANNING

2.1 Overview/Woody Material

The landscape industry has been fashioning growing sites and designing environmental features for centuries. Landscaping as an art and science has information and techniques to bring to site restoration. Designers must continually consider the cultural growing needs and habits of the plant material with which they work. Every landscape or restoration site has relatively specific growing conditions which must be either managed or created for plant life to flourish. The restorationist has the advantage of not only arranging available plants and landscape features but also of establishing a hospitable growing environment.

The process of site restoration can only benefit if the designers and on-site workers have an eye toward natural plant configurations, the balance of the rock, soil and woody material and the overall fabric of nearby or similar plant communities. As discussed earlier in the etiology of site impacts in the backcountry areas of the mountainous West, it can be assumed that most restoration efforts will be directed toward mechanically or artificially disturbed areas. Clues toward plant selection and placement in these disturbed areas can be found in similar, naturally disturbed sites in nearby areas.

Landscapes are more than just the plant life involved. The naturalistic landscape designer looks for a combination of static and transient landscape features. Nearby disturbed sites or similar ecological niches will provide the information needed, despite the fact that human and animal sites are unnatural in their etiology.

Wilderness and backcountry restoration must preserve natural processes and be both site specific and considerate of the total landscape. The restorationist can look to the fallen tree corridors, avalanche paths, riparian areas and fire impacted site for information on which plants to introduce from either on-site or off-site areas.

The restorationist might combine the above advice with his/her own plan for how the plants are placed and into what configuration of landscape features. Figures 1 and 2 show the end result of two different approaches to site recovery. Both locations are ecologically similar and had similar presenting problems.

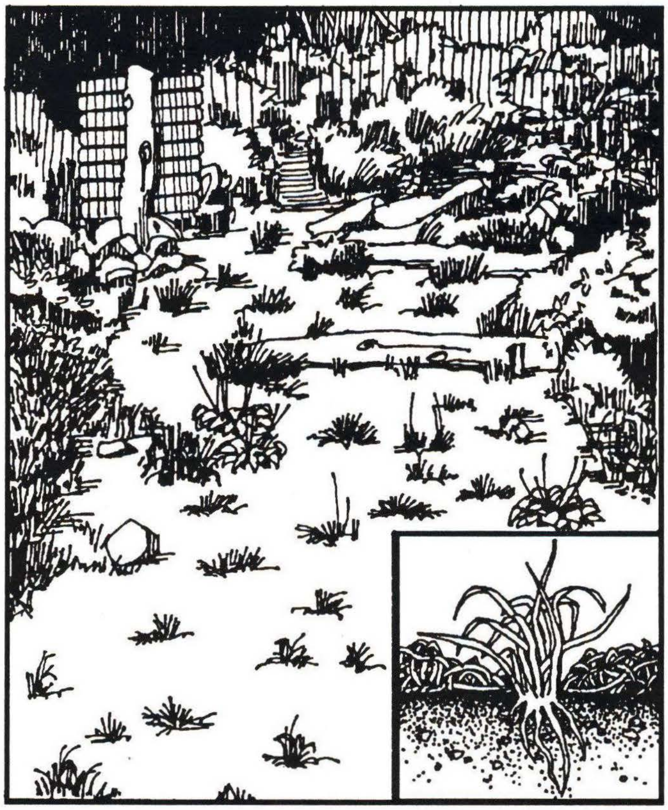


Figure #1 Trail corridor with restoration plants installed in a regular pattern with mulch matting.

Figure 1 shows an intensively planted trail corridor with plants installed in a very regular pattern and protected with curlex mulch matting. The goal of this arrangement was to concentrate one type of early succession planting, capture seeds and prevent trampling. No other landscape features or plants were included in this section.

Figure #2 Naturalized planting pattern with rocks and native mulching.

Figure 2 shows an island within a frequently travelled path. Though isolated, it includes not only a variety of plants, but also rock and pebble attributes which give a more natural look and will encourage small niches similar to those nearby. These, in turn, will provide a variety of microclimates, soils and spaces for the colonization of native species. If available, upright, woody plants such as Alpine Fir and Huckleberry would have been effective additions.

With limited or no plant material available, restoration can occur through exclusive use of nearby materials and landscape design. This is effective in the eradication of unwanted trails and campsites and also during hot, dry periods unsuitable for transplanting.

Figure #3 Horse trail re-route obscured by use of native materials and nearby fallen debris patterns.

Figure 3 shows a horse trail reroute in the Deschutes National Forest. A dearth of understory plants in this Lodgepole Pine Forest forced the work crew to use downed and dead materials in the old trail corridor. The crew not only blocked the trail off, but also simulated the appearance of the adjoining forest floor. In doing so, the eye of the horse and rider will be drawn to the new trail, and the old trail will be allowed to naturalize. In the fall, locally propagated or collected seedlings could be installed in order to promote the growing process.

Another landscape technique is installation of an upright dead branch collected from nearby. Standing dead or dying material is common in most woodland settings and can be used to visually obscure a vulnerable spot, such as a shortcut to a lake. These materials must be buried securely in order to discourage the firewood collector and the forces of wind and snow. Installed below the berm of a trail switchback cut, the upright provides a subtle yet effective deterrent to switchback cutting.

Downed, half-buried logs are a landscape feature common to most backcountry areas. These logs can provide a physical barrier to camping and trampling and the foundation for many naturalizing plants and insects. Securely seated, partially buried logs can be used in conjunction with the transplanted plant material, rocks and other ecological features to obscure and protect impacted areas. Retrieval of actively decaying materials from adjacent areas is useful, but must be judiciously implemented so that other niches are not compromised or destroyed. No more than ten percent of the materials from any area should be removed.

In summary, it should be noted that woody features in the restoration site can be artificially introduced to contribute to a natural design that is both ecologically sound and also resistant to ongoing human impact.

2.2 ROCKS

Use of rock to obscure a restoration site and encourage microclimatic growth of native plants is an elementary and productive restoration technique for patterning rock placements with adjacent rock features. With nature providing the paradigm, several basic tenets of rock design can be followed.

Rocks have basic shapes and are grouped in particular patterns. The three basic rock shapes are: tall and thin, large and squat, arching and flat. From these shapes come the rock formations that are found in natural settings. Imitating these shapes can help visually naturalize a site. Overall balance can be achieved by placing rocks in an asymmetrical and seemingly random fashion.

For the restorationist, replicating nearby landscape features is a workable strategy. Rock is a foundation for this approach. Once installed, rock begins to manage wind, snow and water within a given area. Soil collects, seeds gather, shade is provided, ground covers naturalize and rock-loving plants appear. The foundation for a naturalized landscape has been established. Plants such as *Luetkea pectinata, Kinnikinnik* and *Phlox* encroach or can be planted.

Rocks help seat a variety of plants in rough terrain and their chemical composition encourages desired species to inhabit a given site at the alpine timberline. This is significant because so many damaged sites appear at timberline throughout the Western United States.

Use of rocks and native plants to naturalize an alpine landscape: Timberline Lodge, Oregon

Timberline Lodge is located at 6,000 feet elevation on the South East flank of Mount Hood in Oregon. A major alpine landscape project involving the grounds surrounding the lodge was undertaken in the summer of 1990. The

basic design of the project centered around the naturalized use of large rock outcrops, soil and natural plantings.

The gradient of the involved area was modified to imitate the nearby terrain. Rocks were installed as foundation pieces, larger trees and shrubs were either maintained or transplanted and open areas were created to mimic the meadow-like "drifts" common to this biotic zone.

Rock has both intrinsic and extrinsic value in any naturalized landscape. The restorationist should always consider its use as a valuable on-site element in the restoration plan.

2.3 Planting Design

Planting design is the art of arranging plants in the landscape so that an integrated, natural whole is presented. Plant selection and placement is contingent on plant availability and the cultural growing needs of each species. This process can be implemented through natural and artificial manipulation of the growing environment and by imitating natural design. Native plants common to the growing site will tend to do well if there is adequate soil, light and moisture. The specifics of soil preparation, mulching, irrigation and other plant management factors will be discussed later. Essential to the success of the process are the selection of plants for propagation or transplanting and how they are placed in the landscape.

Earlier propagation efforts were focused on easily grown, pioneer-species plants. Today, propagation programs have become more sophisticated and expansive. These programs provide the opportunity to develop planting regimens with a variety of woody and herbaceous plants including annuals and perennials, grasses/sedges/rushes, ground covers, vines, subshrubs, shrubs and trees.

Plant designs now include groupings or combinations using a variety of indigenous "companion" plants. By studying nearby plant communities, the restorationist can gain an understanding of how plants are massed and connected in the environment. Most native plants are patterned according to the way they reproduce.

Trees, shrubs and grasses that reproduce by seed appear in random, scattered patterns in nature. Plants that propagate by running roots and suckers are found in ever-expanding clumps, spreading outward from the parent plant. This aspect of plant growth is supported by a research project done on the tree clumps and meadow communities in the Cascade Mountains. The researchers describe how the horizontal or distinctly climatic features of wind, snow depth and snow duration in combination with edaphic features often mitigate the fabric of alpine and other harsh climate plant communities (Franklin and Dyrness, 1984). This can be generalized to all plant communities. Hardiness scales used by the U.S. Department of Agriculture and the Sunset Western Garden Book relegate plant growth factors to average annual low temperatures and length of growing season. There is the right place for every plant or collective of plants. This axiom must be recognized by the restorationist in order to maximize time and effort.

Another perspective of the natural mosaic of plants to view them "vertically" as overstory, understory, shrub or ground level plants. These different layers connect ecologically to support each other in addition to giving the designer another layout tool for plant placement. The badger and the hawk look at the same world from different angles—so can the restorationist.

The components of naturalized landscape design are both subtle and obvious. Natural landscape design requires attention to resource information, human activity and management objectives in addition to the aforementioned landscape considerations. On-site and off-site propagation activities need to be outlined along with cost factors, agency resources available, timing and overall agency commitment.

2.4 Site Restoration Worksheet

This is a new working tool being introduced with this publication. Other publications for documenting, monitoring and reporting resource damage are currently available and are listed in the bibliography. This worksheet attempts to provide what has been missing in the past and is a working document that includes the aspects of impact information, work planning, site design and ongoing record keeping.

The suggested Site Restoration Worksheet is intended to be relatively brief, site-specific, prescriptive and maintained as the cumulative work record for each project. It requires a more detailed site design, recommendations and long term planning than similar documents. The site design using landscape graphics can be readily learned by the practitioner and can become the nucleus of planning and field activities.

2.4 SITE RESTORATION WORKSHEET

- Location/Site Identification

- Impact Assessment

- General Resource Information

- Primary Goals

- Recommended Restoration Activities

<u>THREEYEARPLAN</u>

YEARI	YEARII	YEARIII

THREE YEAR PLAN (Continued)

YEAR I	YEAR II	YEAR III

EXISTING PLAN	RECOMMENDED PLAN

RECORDKEEPING:

*(date each activity from the Three Year Plan as it occurs.)

Author - Russ Hanbey, Conservation Resources, Inc. Published by U.S.F.S. Intermountain Research Station

2.4.1 SITE RESTORATION WORKSHEET (SAMPLE)

- Location/Site Identification

General location is the NE corner of Glacier Lake, U.S.G.S. Quadrangle Glacier Peak. Campsite Inventory # is 217, found 50 yards west of lake inlet stream.

- Impact Assessment

Campsite 217 is one of six campsites designated for eradication through restoration due to overconcentration of campsites in a confined area. Reduces vegetation cover, poor screening and proximity to the lake are major presenting problems.

- General Resource Information

Campsite is located at 4,500 feet in the *Tsuga mertensiana* zone. Understory plants represent the Heath Shrub community. Snow melt is late season followed by rapid drying. Approximately 60% of the 600 square foot site is **denuded** mineral soil. Moderate seasonal use is expected in the area.

- Primary Goals

Close and naturalize site and adjoining social trails.

- Recommended Restoration Activities

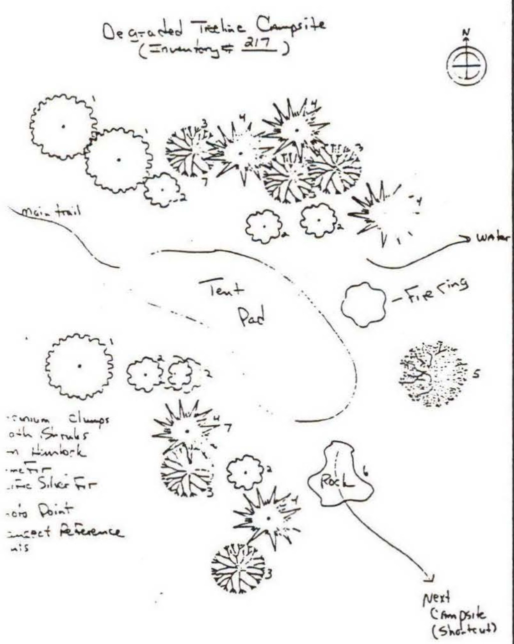
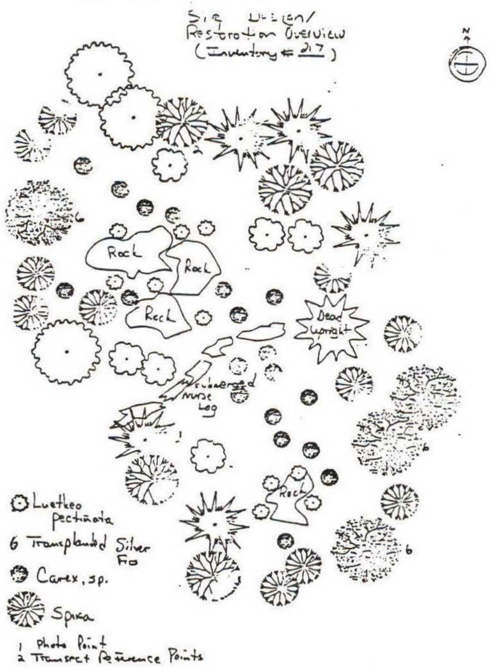
a. Root pruning/transplanting woody plants
b. On-site seedbed
c. Utilization of nearby rock, downed woody plants and mulch
d. Layering and selective pruning
e. Off site propagation regime
f. One season of irrigation
g. Collect and utilize soil from nearby trail reconstruction
h. Signing, education and documentation

THREE YEAR PLAN

YEAR I	YEAR II	YEAR III
rootprune six Silver Firs	transplant/irrigate	monitor
collect Spirea, Leutkea cuttings and seeds/propagate off site	transplant/irrigate	monitor
collect seed from sedge, grasses, lupine	create on site seedbed	monitor, reseed if needed

SITE RESTORATION WORKSHEET (Continued)

YEAR I	YEAR II	YEAR III
collect soil/compost or store	utilize with plantings	N/A
document	document	document
sign and educate	sign and educate	discontinue

EXISTING PLAN	RECOMMENDED PLAN
EXISTING SITE DESIGNS 	RECOMMENDED SITE DESIGNS 

RECORD KEEPING:

***Date each activity from the Three-Year Plan as it occurs.**

Additional comments can be written here in colloquial form.
Other documentation can be attached as desired.

2.5 Record Keeping

The site designs above combine a variety of on-site landscape and propagation techniques in conjunction with an off-site propagation program. Landscape graphics and format are used to present a balanced, proportioned, referenced view of the restoration site.

Utilization of an impact monitoring tool can specify resource damage. From there, goals and activities can be established along with cost and other agency requirements. For the field worker and planner, the site design process supplies the connection for the whole operation.

A simple plot or site plan will have four basic features. The directionality of the site must be identified. Normally, site plans are laid out with North being the top of the drawing. This can be adjusted, but it must be designated symbolically on the drawing.

Next, a working scale needs to be established. Most landscape plans are laid out on either 1/8": 1 foot or 1": 1 foot grid. Precision is not the key, but close approximations of the landscape features to one another are important. Use transects, pacing or tape measure for on-site data collection and a scaling ruler to transfer this information to the site design.

Third, symbols to indicate established landscape features are useful and easy to lay out on the design. Landscape templates and stamps are common in most art supply stores. Hand draw one-of-a-kind features, references to off-site factors and movement patterns. Colored pencils can highlight important aspects such as new plants.

The fourth component of a site design is reference information. References are the numbers, symbols and words used to visually describe existing and new features in the design. These need to be recorded in a systematic fashion on the design itself. It is common to place recommended plant lists in the column next to the site graphic.

Whatever system is used, it should be obvious on the drawing. This will ensure continuity over time as the memory slips or personnel changes occur.

Contour or elevation lines can be included and should relate directly to the established scale. This may be an important addition if, for example, the designated project is a steep trail corridor with drainage/stabilization problems.

Data collection for this process requires a few tools, including a compass, measuring tape, copy of existing documentation and record or field notebook. This can be individualized or directly related to the Site Restoration Worksheet. In general, the field worker and planner need a perspective of agency requirements, a working knowledge of basic landscape principles, an understanding of propagation and the horticultural needs of plants, and a commitment to the tenets of ecological restoration.

Outlined at the end of the next chapter (3.4) is a checklist of suggested restoration practices laid out in sequential order. This Three Year Restoration Plan can be used by the backcountry restorationist in planning the ongoing progression of a site restoration project. Details of these procedures are presented later in this publication.

3.0 ON-SITE RESTORATION TECHNIQUES

Site restoration practices are not new to the mountainous regions of the West. A variety of projects dating back 25 years or more have involved numerous experimental techniques. Most of these have in common the utilization of proximic or "on-site" techniques for rehabilitation.

This chapter describes established and new techniques for using "nearby" resources and landscape/horticultural practices as major components of the restoration effort. The first section deals with procedures involved in site preparation and stabilization. The importance of this aspect cannot be overstated. All subsequent work can be nullified by poor site management going into the project. Aspects of this phase must be considered as an integral part of the three year site restoration plan.

Plant sources, propagation techniques and installation procedures will follow with an emphasis on established horticultural techniques that can be generalized to backcountry work. The restorationist can employ creativity in this area as she/he takes advantage of adjacent native resources for this embryonic stage of the restoration process.

Finally, maintaining a site after the initial work has been completed will be discussed. This is often an overlooked aspect of a restoration project. A commitment to ongoing maintenance may extend over many years, and is vital to ensure permanence and protection of the agency's investment.

Three assumptions should be stated before this section is presented:

1. Human-related impact, including stock, will be managed in conjunction with the restoration effort.
2. Most of the procedures introduced are germane to both front- and backcountry work projects.
3. The mandates of the Wilderness Acts must be recognized by the restorationist and honored throughout the restoration effort.

A successful restoration effort is one that blends so well with the nearby terrain that eventually it will appear if no work has taken place. Careful use of adjacent resources, naturalistic design, low-impact work habits and ongoing site maintenance are key elements in this process.

3.1 SITE PREPARATION

3.1.1 Plant Recovery/Holding Over—Plant recovery or salvage is the act of collecting plants from nearby work sites and using them as transplants in the rehabilitation site. It gives the restorationist the opportunity to capitalize on mature plant material that might not otherwise be available in practical proximity to the restoration site. Typical recovery sites include trail construction, trail reconstruction, road building and campground development sites.

The benefits of the plant recovery process are:

1. Plants that might otherwise have been discarded during other work projects can be re-used.

2. Larger, more mature plants become available. This is very advantageous when companion planting of a variety of successional plants is desired. Vertical development of a restoration site provides shading and visual closure of the site.

3. Historically, woody plants have been the most difficult to propagate. This procedure gives the restorationist the option of using readily available plants in lieu of extensive off-site propagation programs.

4. Plants pulled during trail reconstruction can be taken as a more intact unit, including feeder roots and soil mass, thereby increasing the chances of a successful transplant. Transplant shock can be minimized.

5. Woody plants or perennials that are container grown can become root bound and may not grow beyond the limits of their nursery container when planted. This is less likely to happen with plants taken from a natural setting and transplanted in a timely fashion.

The plant removal approach is similar to general transplanting procedures. Pulling plants early in the day in cool, wet weather is ideal. The restorationist can place the plants in nursery containers, burlap or plastic bags, being careful to protect the root mass and minimize the evaporation of moisture from the leafy part of the plant. A successfully recovered plant is a valuable asset for the resourceful restorationist.

Timing and planning are vital to the plant recovery process. The restorationist should know what work is occurring in the area and be available to pull plants either before or during the construction process. Ideally, the construction crew would assign a person to collect plants as the work project proceeds and to hold them over for later re-use. In lieu of this, plant recovery can be noted on the Three-Year Restoration Plan and factored into the planting schedule.

If construction work does not coincide with nearby restoration work, then recovered plants can be held over for a limited period of time. Holding over requires the practitioner to select a site that will protect the root systems of plant material. Ideal locations include the shaded side of decomposing logs, semi-moist forest floor with a thick litter layer and even a stream or pond side terrain. The plants are dug in and mostly buried with mulch or light soil. The area is moist and protected from drying from the sun and the wind. Plants can be maintained for up to one year if protected this way.

Plants which can be held over include small trees and shrubs, perennials, grassy clumps and some ground covers. Square-foot mats of subalpine turf have been held over in shallow lakes at numerous sites in the Cascades and successfully replanted after several weeks. Fir and Pine seedlings near Trout Lake in Yellowstone have been removed during trail reconstruction, held over and successfully transplanted two to three days later.

A major plant recovery program took place in 1986 along the Sol Duc River Road in Olympic National Park. Prior to road reconstruction activities, crews removed several thousand plants in the fall from the impending work areas and wintered them over nearby in **shaded**, shallow trenches. The trenches were located under the forest canopy in wind-protected, yet moist areas that were close enough to require a minimum transporting of materials. Care was taken to keep the root mass of each plant moist as it was removed, transported and placed in the holding-over areas. Light dirt and mulch were used to **"heel in"** the plants. Even though the plants were not maintained, they enjoyed a 50-60% survival rate over the one-year holding period. Ferns and small evergreens displayed the most resilience over this extended period.

Plant recovery can be factored into a Three-Year Restoration Plan at any point that plant materials become available. Coordination with road, trail or campground maintenance people is vital so that timing and utilization of the "on-site" resource won't be overlooked.

3.1.2 Soils and Site Preparation—Soils are the foundation of any growing environment. Plant establishment and maintenance are contingent on the capacity of the soil system to grow and support organic matter. Soil scientist Pat Green points out that soil is more than a physical mixture of sands, silts and clay: that it is a naturally dynamic body that works like a living organism with physical, chemical and biological properties (Green, 1990). To the restorationist, an imbalance in any one of these three properties can seriously reduce the ability of a restoration site to support plant material. An unfortunate cycle takes place where, according to Green, a reduction in plant cover due to trampling, for example, can cause changes in soil density, soil acidity, soil microbiology and soil erosion resistance. These changes, in turn, limit the capacity of soil to support vegetation. Soil is dependent on this vegetation for its ongoing fertility and ability to "aggregate soil particles and cycle nutrients" (Green, 1990). Add to this the reality that fertile soils in remote areas with harsh climates may be thousands of years old in their undisturbed state, and the challenge becomes exceptional.

There is no currently documented procedure for reproducing ancient soils. A restoration plan must be designed that either works around or compensates for the limiting factors that soil development presents. For the weekend gardener, soil development is a matter of producing a "friable" medium that provides a balanced mix of soil particle sizes, good drainage and moisture-holding capacity. Particles of stone from disintegrating rocks and minerals, humus (decaying organic material), water, air and microorganisms (bacteria and fungi), and dissolved mineral salts make up the classic soil profile. Degraded soils in Wilderness terrain do not replicate this profile; therefore, revegetation without intervention may be impractically slow.

The chemical, biological and physical properties of soil that promote and support plant life can be compensated for in remote, harsh settings by plant selection, natural process assistance and proactive site preparation. Site preparation is centered around stabilization, erosion control and re-creation of natural topography (Merigliano, 1990).

Site stabilization and preparation involves a sequence of techniques that can be prescribed in the Site Restoration Plan. Pat Green (1990) succinctly describes the role hydrology plays in soil restoration by stating, "How soils and landforms process water will determine if the soil can stay in one place long enough to heal and what kind of plant community can develop on the site." The first task

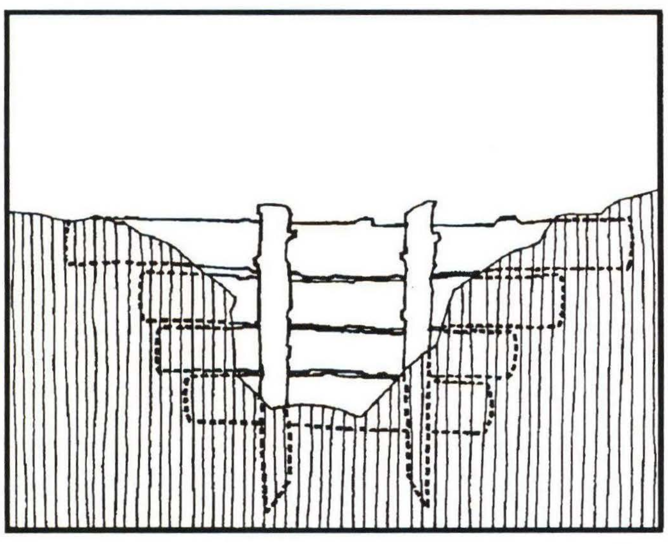
of the restorationist, then, is to observe and process the effects of erosion and mass wasting.

Downward-flowing surface water may be seasonal and not easily observable, but the overall impact is one of rutting, furrows and gullies. Gravel and sand deposits appear, roots of woody plants are exposed and rocks unnaturally emerge. Unchecked subsurface flow releases slabs of connected soil and plant tissue. In a restoration site, which might be an old tent pad or a switchback trail cut, the causal agent for erosion can usually be traced back to human, machine or domestic animal influence. Cole discussed site impact management in an earlier chapter, concluding that the source of erosion must be mitigated before a long term solution is achieved.

After the human factor has been adjusted for, the long-lasting effects of water management can be more solidly guaranteed. For example, if a pristine Bunch Grass zone area in Eastern Oregon is rendered unusable as a potential campsite due to exceptional erosion problems, the symptoms may be obvious but not the precipitating event. In this case, random cattle grazing could be the culprit and will continue to be so until the grazing is controlled. After the cattle are removed from the cycle, then genuine repair of the land can begin.

The tools of the restorationist are similar to those of the trail builder. In order to stabilize a site, water will need to be controlled. The trail builder manages water flow through the use of water bars, drainage dips and trail structures. The restorationist utilizes check dams, and contouring, and avoids permanent structures.

The technology of water bar and drainage dip construction requires permanent features to be constructed that will divert water off a trail and withstand human or animal impact. They are integrated into the trail corridor and are passively low profile until water overburdens the tread.



Check dam or "gully plug" cross section

In contrast, a check dam (or gully plug) is designed to impede water flow and allow for soil buildup. They are positioned at right angles to a slope and secured primarily by staking or other bracing. A platform and anchoring feature needs to be constructed that is durable enough to withstand gravity and flushing by moving water.

In a gully, the top of the check dam should be brought up to the same plane as the surrounding terrain. On an open sidehill the check dam will need to be partially buried on an inward sloping bench and secured with stakes. The uphill side of the log or rock barrier can be backfilled with fertile soil and planted with native plants. Both features inhibit the downward movement of soil and promote the accumulation of soil particles. Each station can be subsequently removed or allowed to decompose. Plants will grow in and around check dams, helping obscure the dams and counteract the forces of erosion.

Steep hillside check dam with plantings

The check dam was used in Yellowstone to stabilize expansive fire breaks built on steep slopes after the fires of 1988. It is appropriate for rutted trails or switchback cuts, and for "open" sites that present a gradient too steep to hold developing or imported soil, for large rocks and solid woody debris to be added to a restoration site as part of the landscape plan. They can be installed in a naturalistic fashion and can serve the dual purpose of either impeding or holding water and as microsites for plant growth.

3.1.3 Natural Contouring and Soil Sources— Introducing native soils to a restoration site is a productive, albeit challenging exercise. The goal of soil introduction is to recontour a degraded site or trail corridor so that it matches the nearby terrain and provides fertile media

for new plant growth. Finding, transplanting and securing adequate soil will test the creativity of the restorationist as he/she develops the work site.

It is suggested that a soil bank be created where similar soils from nearby work sites, such as a road cuts, trail construction or campground development are gathered and stored instead of discarded. The soil bank would be identified on the Restoration Plan and situated in a protected yet accessible location. The value of saving and storing this material cannot be overstated.

Introducing non-native soils is both ecologically questionable and generally impractical. Plant growth of even early successional plants requires some soil organic matter for survival. Therefore, any source of discarded soils in proximity to the restoration site must be identified as a valued resource. Broadcasting available soils over a restoration site, in conjunction with naturalizing a site through landscape techniques and mulching, is ideal. This allows for seed germination inoculation of indigenous soil microbes and overall appearance.

Steven Arno, author of "Timberline" reminds us that deep rooted trees and shrubs are more dependent on the chemical composition of underlying rock or substrata for successful growth, and soils that are too thickly applied may actually inhibit woody plant growth (Arno, 1984). Roots of these plants can become rapidly desiccated during drought periods when limited to a nutrient-rich topsoil.

Having too much soil to rehabilitate a site will probably never be a problem that plagues the restorationist. The opposite problem will more often be the case; and so, selective use of available organic material will need to be exercised. Installing acquired soils in conjunction with each transplant or seed bed is the best alternative. The restorationist should simply dig in the nutrient rich material with the parent soil as he/she proceeds. A thin layer scarified into the surface level of a seed bed is also productive.

If no expendable soil source is available, there are other sources of soil-like material available for the resourceful field worker. Once again, it is assumed that these sources are limited parts of natural processes occurring elsewhere and should only be collected and integrated into transplants in a judicious fashion.

Burrowing animals, such as marmots and badgers, will often leave **tailings** outside of their underground habitat that are rich in nitrogen and other processed nutrients. These can be collected and mixed into transplant media on-site. Ground squirrels and larger animals leave "castings" and manure that have concentrations of potential plant nutrients. The caution here is to select small amounts of "aged" samples of both types of these processed materials.

The backcountry compost site mentioned earlier is another source of soil-like material after it has been allowed to mature. The base of windthrown trees often exposes burrow sites along with natural depressions that may accumulate soil. In all cases, the operational strategy is to not compromise one area for the sake of another. Once again, the rule that no more than 10% of any on-site resources be taken away is appropriate.

The most important nutrient that soil provides plants is nitrogen. Unfortunately, it is the most easily depleted and most transient of the soil chemicals. Installing "nitrogen-fixing" plants as the first choice in the planting sequence is one way to rehabilitate existing soils so that they can support future permanent species. Often, these are easy plants to introduce or pioneer through establishing friendly cultural growing conditions.

Farmers call nitrogen-fixing or nutrient restoring plants "cover crops" and intentionally rotate these with their cash crops in order to revitalize their soils. Expanding this process has not been fully explored in the restoration of wilderness areas but bears serious consideration. What has been shown is that a number of plants, such as lupine, alder, ceonothus, shepherdia and peavines, can be introduced to convert atmospheric nitrogen in the soil and thereby set the stage for a later succession of plant growth (Green, 1990).

In summary, the Three-Year Restoration Plan must be designed to include both site stabilization and soil development. These components precede plant installation and should be factored in as first year activities along with people/livestock management.

3.1.4 Soil Solarization—David A. Bainbridge reports in the Winter, 1990, issue of "Restoration & Management Notes" that extended use of the plastic sheeting technique can effectively kill many common weeds, seed and soil fungi. This would be a giant step in the direction of how to eradicate invasive weed species, especially in the Intermountain Region where stock use and grazing are historically common. This is a procedure that would, of course, take place before desired seeds are introduced.

"Solarization" has been used in different forms by farmers for centuries to sterilize weed infested crop land. For the backcountry restorationist it would be most effective on sunny sites where the soil temperature (to one inch) under plastic can reasonably be expected to rise above 40 °C (101 °F) for several weeks or over four to six weeks if occasionally cloudy.

The solarization process begins by loosening the soil in the work area and laying 1-2 mil plastic over it using the previously mentioned technique. Heavier plastic, 4-6 mil, will be needed in windy spots. Overlap the object area with the sheeting and secure the edges in order to contain heat and moisture. This technique has not been shown to harm beneficial soil organisms such as mycorrhizae and earthworms. Proceed with the prescribed restoration process once this site preparation technique is complete.

Table 1 gives data on the response of 19 common weeds to solarization.

3.1.5 Composting—Composting is introduced here because of its potential as an on-site source of mulch and organic planting media. Compost is a dark, crumbly and earthy-smelling form of decomposing organic matter. It is a process of returning wasted material to the soil in usable form. This is an issue in remote areas where natural soil amendments are scarce. Healthy plants, of course, rely on healthy soil.

Composted material in the soil improves plant growth by helping to break heavy clay soils into better texture by adding water and nutrient-holding capacity to sandy soils, and by adding nutrients essential to any soil.

It is suggested that the Three-Year Restoration Plan include the possibility of an obscure compost site near a

restoration site. The compost site would have the additional advantage of providing a location for processing backcountry debris. This debris might include the following items:

1. Dried horse manure
2. Non-meaty or non-milky food wastes
3. Trail-side brush debris
4. Leaves or needles raked from a campsite
5. Loose-fibered paper products such as egg cartons or tea bags
6. Ashes from fire rings

The key to composting is to provide for a combination of biologics, compostable materials, surface area, volume, moisture, aeration, time and temperature. Microbes, fungi, protozoa, insects and worms are necessary for decomposition. They will appear on their own, especially if the pile is located in a protected site near where natural decomposition is taking place. This would exclude an exposed talus slope at 9,000 ft. in the high Rockies, but include a tree clump or active meadow system in the same locale.

The material mix of the compost is important. Carbon from woody materials is needed for energy by microorganisms and nitrogen provides protein. The materials are basically brown and green, provided at a ratio of 30:1. Dead and dying woody material is easy to find throughout the mountainous West. Finding nitrogen-rich material is more challenging. Harvesting leafy material from herbaceous or grassy meadows is one option but should be tempered with restraint. An alternative is the introduction of omnipresent horse manure or human urine. This is a resource used successfully in many developing countries of the world and might be quite entertaining for backcountry rangers and nearby rodents. Food wastes are acceptable but should be buried well into the pile. Meat, cheese or oily products should not be used.

A compost pile can be on the surface or be partially entrenched. Ideal volume is between three and five cubic feet to allow for balanced energy within the pile. The surface area of the material available to micro-organisims and the elements can be increased by chopping or pruning the composted material into small pieces.

Extremes of rain or sun can disrupt the compost pile. Material from the center of the pile should be only as moist as a wrung-out sponge. Water or woody material should be added as needed to keep the pile loose and adequately moist.

Given enough time, all materials break down. At high elevations the process will be slower but effective nonetheless if the aforementioned procedures are followed. The North Cascades National Park and Appalachian Trail Club have both successfully used composting toilets under extreme environmental conditions for many years. The restorationist can work with backcountry personnel to set up and manage compost sites with relative ease. Once again, the Restoration Plan should include this early on, so that a limited yet potent source of on-site soil enriching material can be available when plants are introduced to the restoration site.

3.2 On-site Plant Propagation Techniques

3.2.1 Transplanting—Most early revegetation efforts at smaller sites throughout the mountainous regions of the West relied heavily on the use of indigenous plant material taken from adjacent sites. Plants were selected from undamaged areas and moved immediately into the object areas as clumps or sods of plants.

The advantages of transplanting nearby plant materials are a high success rate, rapid establishment of cover, immediate seed source and better success in harsh conditions. These advantages still hold in current practices especially if combined with the principles of genetic purity, design using plant combinations, and the potential of plant recovery or salvage.

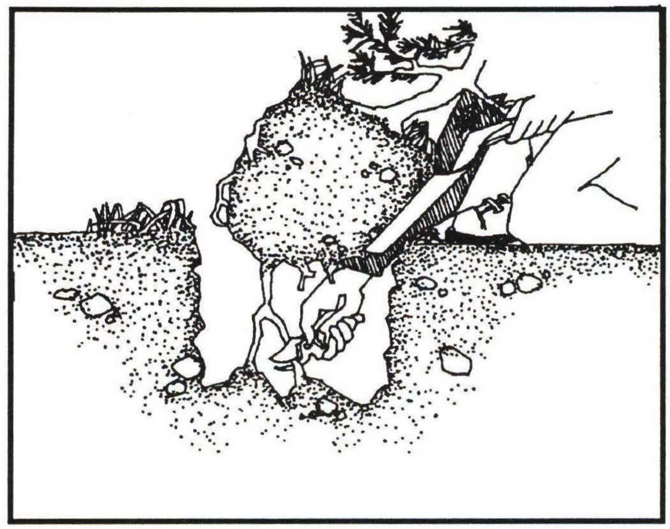
Unfortunately, current ethics minimize the dependence on transplanting because of related damage to the providing area. Disrupting one plant community to benefit another must be done selectively. Plug holes or divots resulting from transplant activities at Green Mountain and Snow Lake, herbaceous meadow sites in wilderness areas of the North Central Cascades, are still visible after many years. Miller and Miller (1978:14) discounted transplanting at Cascade Pass and Mount Rainier because there were no undamaged areas nearby to serve as sources for field transplants.

Conversely, transplants were successfully utilized by this author in 1990 near Timberline Lodge on Mount Hood after a **root pruning** process from trees selected from compromised terrain in adjacent ski runs. Additionally, plugs were recovered by the author from overhanging trailside sod in 1984 on Green Mountain in the North Cascades and successfully transplanted into recovery sites nearby.

Since field transplants cannot be the sole plant source for a restoration site, the procedure must be utilized in conjunction with other on-site/off-site sources and factored into the Three-Year Restoration Plan. On-site transplants can be more economical because they provide immediate installation of relatively mature plants in lieu of one to three years of nursery-grown investment. They can also provide erosion control and soil stabilization if planted closely together. Except for small jobs, the needed numbers of nearby plants are not generally available within a viable collection radius of the restoration site to justify sole reliance on field transplants.

3.2.2 Procedures for Transplanting Field and Container-Grown Plants—Schreiner and Moorhead (1979) found that mat-forming plants, grasses, sedges and plants with runners have the highest success for transplanting. These include clumping grasses, herbaceous perennials and subshrubs. Examples are Sword Ferns, Western Strawberry, Coneflower, Drummond, Rush and Luetkea. Woody plants of moderate size that have been root pruned are also available to the restorationist. Woody plants that are brittle have long horizontal roots or originate from dry sites and should be avoided. Examples of this are the heaths/heathers, Salal, Oregon Grape, Bracken Fern and Vine Maple. Plants with long tap roots such as Lupine and Ponderosa Pine are also unsuitable.

Several plants suited for transplanting: Cone Flower-Wild Strawberry



Proper lifting technique for transplanting larger plants

If the site plan calls for a variety of plants, then pioneer species, along with other plants, will need to be identified nearby or propagated. Disturbed site plants, if properly transplanted, have the highest survival rate and merit primary consideration. Unfortunately, many of these are annuals and not available for transplanting. Beyond these plants, the Three-Year Restoration Plan can include many selectively propagated or transplanted species that lie farther down the successional chain.

A plant selected for transplanting should be soaked the day before removal and moved early in the day or during cool, cloudy weather. Stress on plants is much higher in warm temperatures or direct sunlight. The turgid strength within a plant's stomal structure has been shown to be highest near dawn and can maintain a plant more optimally during a transplant procedure.

If possible, the plant should be moved when it is dormant. Second choice is in the fall during wet weather. Third choice is anytime that the transplant can be maintained afterward with watering and possible shading. Moving the plant immediately after digging is ideal; otherwise, practice "holding-over" techniques discussed earlier. **Transplant shock** resulting from moisture stress and moving plants during their flowering/fruiting cycle can be reduced by properly timed movement of a plant.

Once the transplants have been selected and the timing seems appropriate, the process of "lifting" the plant should begin. This procedure is also appropriate for a "plug" or tight grouping of plants. A scoop shovel held vertically or a tree spade can be used to dig down deeply around the **dripline** or outer growth perimeter of the plant. The plant should be encircled with the tool, cutting the lateral roots. A set of hand pruners is needed to cut resistant roots. This is a much better procedure than forcing a shovel through heavy roots. The plant should be encircled once again, levering inward with the shovel thereby "lifting" the plant. Reach underneath and sever remaining roots with the pruners while moving the plant and attached soil into a carrying device. Heavy plastic bags, buckets or tarps are ideal for this function. Move the plant immediately to the prepared planting hole, "holding area" or temporary site out of the sun. The roots must not be allowed to dry out. Keeping the root mass of the plant saturated with water throughout the process works well to ward off desiccation.

Overdig the planting hole about $^{1}/_{3}$ times larger than the transplant, including the bottom of the hole. Mix some of the removed soil with soil from the parent plant nearby. If the original soil is not friable, use nearby duffy litter and possibly bonemeal or bloodmeal ($^{1}/_{3}$ cup) and backfill the lower part of the hole.

Bonemeal is commonly used by the landscape industry for ensuring root development in new transplants. It is an organic substance, rich in phosphorus, and will be very transient as an introduced fertilizer in wilderness areas.

Center the plant in the prepared hole with the crown of the plant at about the same elevation as the original placement. Roots can be manually spread and pruned to fit the hole and to seat the plant in a balanced fashion. Backfill the edges around the root wad, adding bonemeal, duffy litter and original soil. Press the soil and plant downward to stabilize it to ward off frost heave and remove air pockets. Create a depression around the edge

of the plant in order to catch and hold water. This can be tested when watering.

Soak the new plant twice, the second time with B-1 hormone mixed in. This is another lightly used, transient substance that can reduce transplant shock and increase plant survival.

Protect the base of plant with light forest litter or shading. This mulch will preserve moisture in the summer and insulate in the winter. Don't use pure wood chips or sawdust. These materials have been shown to rob nitrogen from the soil as they decompose. If transplants are selected from nearby, then the transplant hole must be backfilled and obscured with native litter. Settling of the hole must be accounted for by overmounding the fill material. Never remove threatened or endangered species or more than 10% of a given species from the collection zone.

Care must be taken when moving to/from the transplant sites. Wearing soft-soled shoes forces the worker to be more careful. Alternating paths around the collection site also helps reduce resource damage.

3.2.3 Special Notes for Transplanting Container-Grown Plants—Container-grown plants of native species are primarily grown in nursery operations. They are transported to the restoration site by helicopter, backpack or pack stock. Plants grown in a nursery operation will need to be **hardened-off** and monitored closely before transplanting in the backcountry. Three factors to watch for are rapid drying, broken stems and root-bound plants.

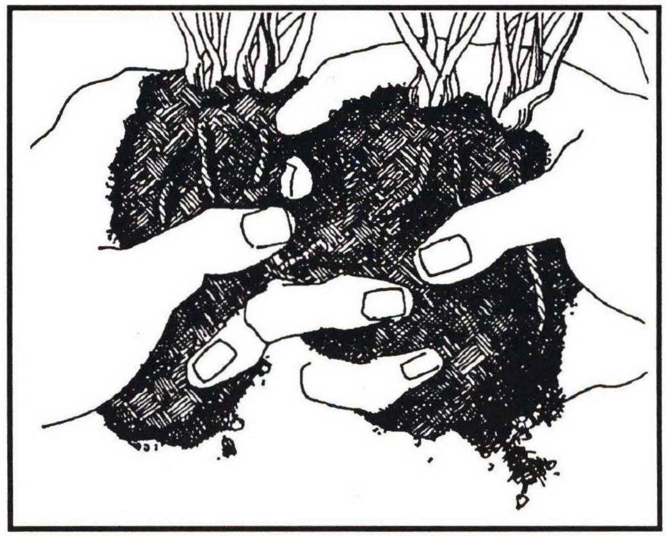
Plants that live in containers dry rapidly; therefore, they need to be monitored for adequate moisture throughout the transportation and transplanting process. An overdry plant is obviously lighter to the feel. Sample plants can also be eased out of their pots and checked for dryness. Packing plants in wet burlap bags or plastic bags with moist moss are two vehicles for keeping plants moist. Damage to stem and branch structure is common as plants are moved about. A plant may be root-bound where the root structure in the container is so dense that it is entangled with itself and will often not hold moisture when watered. This can be compensated for by dipping the entire pot in water until bubbles stop appearing. Specialized fertilizer for pot-bound plants is available, but quite expensive. Damage to stem and branch structures is common as plants are moved about. Removing the plant from its pot and packing it firmly with other plants and mulch or moss actually protects against excessive breakage and makes transportation by helicopter, mule or backpack much easier.

When installing a pot-bound plant, feel free to hand-loosen the roots and cut any excessively long roots that unwrap in the process. Sometimes a sharp tool, such as a hand pruner or a knife, can be used to slice the edges of the root wad of the object plant before it is planted. All of these precautions will ensure more vigorous growth of a container-grown plant in the field. Site preparation and transplanting procedures are identical for container-grown plants as for the field-transplanted plant.

3.2.4 Root Division—Root division is a simple technique for vegetatively reproducing herbaceous plants and grasses from a limited supply of parent plants. This can be done as an on-site or off-site procedure and has the advantage of immediate duplication of transplantable smaller plants that are genetically identical to provider plants. Divided plants can carry with them established roots, soil microbes, plant biomass and potential on-site seeding systems.

Root division requires the practitioner to lift field plants or remove nursery plants from their containers and separate the parent plant into several subdivisions. Each division becomes a new, self-contained plant that can be repotted or spread throughout the restoration site. Multiple-stemmed perennials, grasses or plants that produce off-sets or runners are good candidates for this procedure. *Fragaria* sp., Alpine Timothy and Phlox are good examples. Avoid plants that are woody (Heather), have tap-roots or are heavily tuberous (Beargrass).

Procedurally, division is easy. Lift the object plant and tease apart the roots and stems into smaller plants. Try to keep root wads with attached soil together and moist. Loosely constructed plants can be eased apart by hand much like separating a peeled orange. Each small bundle has the potential to grow into a new, larger, self-contained plant given proper transplanting and optimal growing conditions.



Manual technique for root division

Tightly compacted root wads may need to be separated using a shovel, hand trowel, pitchfork or other prying tool or combination of tools. Off-sets or runners that have rooted can be separated and replanted without disturbing the parent plant and the **stolons** of the grassy plants can be divided into numerous **plantlets**.

Timing is important. Plants that flower early in the season can be separated after flowering or in the fall. Plants that bloom later in a growing season, such as tall grasses, are best divided early in the growing season. Cut back some of the leafy or stem growth in order to reduce transpiration and divert energy to root development after the divided plants have been installed.

Replant utilizing appropriate transplant procedures. Start early in the day, keep everything moist, replant rapidly and utilize transplant hormones as needed.

Plants that are separated from root-bound pots in the greenhouse can be divided and placed in smaller pots. The obvious benefits from this are the multiplier effect of replicating numerous, genetically identical plants from one source and the accelerated growth cycles that can be facilitated in a greenhouse setting.

3.2.5 Root Pruning—One of the most challenging aspects of site restoration is the acquisition of mature plant material for use in the restoration site. In order to add visual relief, shading, seed sources and companion plantings, the selective use of larger plant material gathered within the collection radius of the restoration site is one alternative. Root pruning is a technique available to the restorationist to prepare these plants for transplanting into the worksite.

Root pruning is commonly used in the nursery industry as a procedure to maintain and prepare field-grown nursery stock for shipment to markets. The grower of woody plants can maximize his/her property by confining as many plants as possible in the available space. Space underground is the most limited yet most valuable for the nurturing of larger plants. It has been shown that more plants can be grown closer together if their root systems can be reduced.

Root pruning is a labor-intensive yet effective method of forcing the root wad of a tree or shrub to stay confined to a small area under the **dripline** of a woody plant. This procedure not only encourages the proliferation of valuable root hairs within the root system, but also enhances the easy transporting of the plant at the appropriate time (usually late Winter/early Spring as a "balled-burlaped" specimen).

The procedure is straightforward. After the desired plant material has been selected, dig a circle as deep as possible directly downward around the dripline of the plant. This severs all of the lateral roots of the plant and will encourage new, finer root growth in and around the crown of the plant.

Proper angle of shovel for root pruning

The tool of choice for this is a tree spade. If not available, a scoop shovel or fire shovel can be used if care is taken to make sure the downward angle of the cut is parallel to the trunk of the plant and perpendicular to the ground. Especially thick roots that lead uphill and are connected to a parent clump elsewhere, can be parallel dug with the tree spade, taking care not to sever this root. This is common in subalpine areas and can be avoided by selecting isolated plants from flat terrain.

Once again, timing is a key to this procedure. Root pruning prepares the plant for future transplanting. Selected plants can be first root pruned in winter (if possible), early spring or fall. This allows the plant to compensate and adapt while the plant is relatively dormant and there is maximum moisture in the area surrounding the roots. Once the plant has been initially root pruned, the technique can be repeated at any time, following the original cut lines.

Allow at least one year for a plant to adjust to the operation before digging and moving. An ideal sequence would be:

Fall—initial root prune
Spring—re-do
Fall—transplant

Follow the aforementioned process for transplanting in the backcountry. Root-pruned plants are much easier to pull and move than plants without this preparation. More important, survival rates will be much higher.

In early Fall of 1989, this author root pruned 25 plants of the following species:

Subalpine Fir
Whitebark Pine
Mountain Hemlock
Mountain Ash

These were taken from the ski slopes adjoining Timberline Lodge on Mount Hood, Oregon, to be used in a native plant landscape project in front of the lodge.

The plants were transplanted in hot weather in late July of 1990 with a 95% survival rate through July of 1991. These plants were installed in a large area (1/3 acre) in combination with nursery-grown grasses, sedges and flowers, thereby providing a more complete initial landscape effort. The plants selected for this procedure at Timberline were between two and five feet in height. Smaller trees can be moved without needing root pruning if enough of the surrounding soil is taken. Larger specimens are not desirable because of their established dominance in their own plant community and difficulty in moving. Weight and bulk are a mitigating factor here.

This process should be blended with the decision making process of collecting on-site plant material. Care should be taken to not compromise existing plant communities; therefore, only remove trees/shrubs that would otherwise be lost or occur in such frequency that separating one from a collection area can be justified.

A side benefit of this technique is that a root-pruned plant designated for transplanting will continue to thrive if the decision is made later on to not remove it. Trees that were root pruned in late August of 1988 near the Picture Lake and Artists Point areas of the Mount Baker Ski Area, Wash. (elev. 5,000-6,500 ft.) were observed in the summer of 1990 to be vigorously growing, despite not having been transplanted to a restoration site.

The Three-Year Restoration Plan should include a systematic approach to preparing larger, on-site plants for transplanting through root pruning. This should be decided and implemented in the first or second year.

3.2.6 Seeding Beds: Revegation/Restoration by Seeding—Seeding has been one of the most common methods for "revegetation" in mountainous terrain throughout the world. A considerable amount of literature exists describing various experiments in this area. Most of this information describes the use of non-native or agronomic species to rehabilitate or stabilize such sites as high altitude mine tailings, ski run slopes, road cut, banks and fire-damaged sites. Many of these projects have been successful in the establishment of plant covers in difficult terrain. For the purposes of this guide, we will introduce some of the proven techniques for on-site seeding and not the specific species involved. It is our contention that seeds of non-native species should never be utilized in Wilderness, park or pristine backcountry areas.

Non-native species can initially compromise native plants by either heavily clumping or forming dense root masses. This robs nutrients and moisture from naturally occurring, early successional plants. This surface-level development can inhibit native trees and shrubs, leading to poor soil stabilization over time. Planting of non-native species has been observed to accelerate erosion within a few years of fires in certain situations (Yellowstone Report, 1988).

Fire suppression activities related to the Greater Yellowstone Ecosystem fires in 1988 resulted in the establishment of numerous catlines (caterpillar dozing of firelines) and helipads. Near the National Park, National Forest personnel air seeded some of the most erosion susceptible sites with "short-lived" wheat and cereal rye. It was the observation of this author in 1990, supported by Park Service recommendations (Report, 1988), that the short-term effect of utilizing these commercial mixes of wheat and rye was deleterious to general ecosystem health.

For ideal native seed establishment, three elements are needed: warmth, moisture and growing media. On a denuded site, heat will be available (unless the site is in deep shade) but loose soil and appropriate moisture are often missing. Soil **scarification** and elemental augmentation through fertilization can assist but need to be used with caution in Wilderness areas. Scarifying or loosening the soil can be utilized with "natural seeding" where nearby seeds are dispersed by natural processes.

Working against sole dependence on natural seeding are the probable dearth of wind-borne seed sources nearby, the low viability/germination rates of many harsh-climate plant species, and the perennial versus annual growing habit of many desired species which leads to low seed production.

Result of successful on site seeding operation

Successful natural seeding experiments have occurred when adequate season-long moisture and local prolific seed sources were available, such as the Lyman and Image Lake projects in the Glacier Peak Wilderness (Smith, 1978). Once the seedlings have moved beyond the germination stage, many degraded sites cannot maintain the growing needs of emerging plants. Current practices recommend the use of mulching systems and natural landscape features to assist in native seed dispersal and nurturing. (Refer to *Landscape Considerations* and *Site Design* in Section 2.0 for more information on this.)

Natural seeding works best in conjunction with manual seeding of a restoration site.

Manual seeding can accelerate the restoration process greatly. The introduction of high densities of native seeds has proven to be very effective, if, once again, optimal growing conditions are established. On-site seeding in selective sites preempts the use of transplants, off-site nursery programs and dependence on natural revegetation. Conversely, manual seeding is slower and less visually obvious than transplanting, requires a tight and labor intensive seed collection system, and limits the restorationist to a narrow range of plant species. It is recommended that manual seeding be done in conjunction with other on-site techniques.

To aid in the decision making process of how much to invest in seeding programs, Miller and Miller (1978) have developed the rating system given in table 2.

Since 1978, several techniques have been developed to compensate for environmental stresses rated as highly problematic by Miller and Miller.

To compensate for summer dryness that would inhibit seed germination a procedure of covering a seed bed with 4 mil. clear plastic sheeting has been developed by Bill Lester, North Cascades National Park. The sheeting acts as a cover that not only protects seeds, but also raises the soil temperature and traps moisture. This has proven to be very effective in rapid seeding establishment in a variety of harsh environments, including exposed, high-elevation ridges in the Cascade Mountains.

The procedure for this easy and inexpensive propagation technique is as follows:

1. Establish seed bed in fall just before winter, or early spring just after snowmelt.
2. Collect seeds from nearby and store or disperse if ripe. "Ripe" seed usually appears between August and November. Mature seeds on a plant that produces dry seeds are ready for collecting when they're dark and dry. Plants that produce seed in a fleshy fruit or berry are usually ready when the berries are most brightly colored. Optimal collection time is just before a plant would naturally disperse seeds from a shattering seed capsule or in a fruit consumed by birds or animals.
3. Loosen but don't rake surface soil. Walking the area with old crampons or hob-nail boots can give the desired perforation depth and spacing.
4. Disperse or spread seeds by hand or portable grass seed spreader over desired area. For large seeds, such as Lupine, establish a seed density that is visible to the eye from a standing position. Small seed, such as Sedge, can be mixed with sand and spread evenly over the site.
5. Cover seeds with a light natural mulch or commercial mulch mat. Not required, but helpful later on.
6. Cut a piece of plastic to fit the growing area. Try not to make the plastic geometric, so that resulting growth doesn't look regular.
7. Lay plastic over site and secure with rocks, branches or zip lock baggies filled with sand or gravel.
8. Monitor for germination. One to three weeks, or next season if setting up bed in fall, should do if it is sunny.
9. Be prepared to lift plastic on hot days to aerate and water after germination.
10. Remove plastic once dicotytedonous plants have true leaves and monocotes are over one inch tall.

Before and after results of seeding under plastics

Plastic can remain if germination is slow. Plastic was removed after three seasons at Artist's Point Trail, North Cascades (6,000 ft.) to reveal healthy but yet delayed plant growth. Monitor the site during droughts and high intensity light periods in order to guard against scorching of seedlings. At any elevation, 100° + surface temperatures can occur under plastic. Though unattractive, seeding under plastic is temporary and inhibits trampling by the public. It can accelerate the establishment of native species and help stabilize a site. This can work to the advantage of the restorationist in the elimination of weeds and soil pathogens.

3.2.7 Seed Collection/Storage—On-site manual seeding requires a collection and storage system. This will become an integral part of the Three-Year Restoration Plan and propagation cycle and can be implemented

by knowledgeable volunteers or trained field workers (or contracted). Some precision timing, knowledge of plant species and simple equipment are required.

Seed propagation, whether on- or off-site, has the advantage of plant production that is more genetically random and diverse in nature. All seeds, especially those collected in the wild, are hybridized versions of parent plants. Seeds collected randomly from adjacent gathering areas will carry the strengths and weaknesses of their genetic providers. This will provide the restoration site with a variety of plants both within and among species. The presumed advantage of collecting seeds from adjacent sites is a diverse and pre-adapted crop of plants within the growing site.

Regina Rochefort, in her treatment of seed collection in Mount Rainier National Park, establishes criteria for seed collection. They are designed to ensure the genetic and locational integrity of the seed source and take advantage of the inherent adaptability of indigenous seed.

1. Collect seeds within the same plant community type as the area adjacent to the impacted area.
2. Stay within topographic and vegetation boundaries around the impact: don't cross a ridge or walk from a subalpine meadow through a forest to another meadow to collect seed.
3. Stay within broad elevational ranges: 1,500' to 3,000' or 3,000' to 5,000', etc.
4. Only collect about 50% of seeds in any given area: leave some for natural processes. (Rochefort, 1990).

Every native plant has an ideal window of time to have its seeds collected. Each plant has its own dispersal system that can range from wind-borne to water-borne to explosive. Whatever the vector of dispersal, the restorationist will need to select an optimal time for seed collection depending on species and weather. Utilizing local resources such as native seed companies, agency botanists, garden/native plant clubs and plant guides should provide adequate initial information. Personal experience and documentation within the Restoration Plan will fill later gaps.

In general, seeds and seed pods will reveal themselves after the bloom cycle of the object plants. Grasses, rushes, sedges and ferns won't provide the inflorescence of a Lupine or Salmonberry, but mechanisms do become obvious upon observation. The flower stocks of Bear Grass (*Xerophyllum tenax*) and the black spike of ripe *Carex nigricans* are examples.

Most species produce ripe seed between August and November. Mature seed or plants that produce dry seeds are generally dark; plants that produce seed within a fleshy fruit or berry are usually ready for collection when the berries are most brightly colored.

For most species it is best to collect seed in dry, calm weather. The restorationist should be equipped with soft-soled shoes, paper lunch bags, scissors or pruners, and a labeling pen. Dry-fruit dwelling seeds should be gathered in paper bags or envelopes so they can begin drying and be stored without rotting. An exception to this is seed from plants in the Buttercup (Ranunculaceae) family. Gather these seeds and place in plastic. Collect and store seed from fleshy-fruited species in paper containers also, in order to inhibit molding. **Be very careful to accurately label each bag with:**

Location:
Species:
Date:

Large volumes of seed can be collected using a butterfly net if the desired seeds are loose. Be sure to release captured insects. Placing an apron around the base of object plants and allowing natural processes to deliver seeds is another technique. Small portable vacuums have been used to strip light seeds from their sources. Cutting an entire stalk, then allowing separation in the storage bag is productive. Once again, try to limit collection to 10-20% of available seed from any given area.

There have been no reports of successful on-site seed bed growth of scattered flesh-fruited species. Many of these need cold stratification, scarification or passage through an animal's digestive system. Off-site propagation programs will be needed for these plants.

Dry-fruited species will need their seeds cleaned before storage or on-site dispersal. Winnow the seed from the chaff by gentle shaking, agitation, blowing, manual separation or sieving through a strainer. Storage of seed can take place in most air-tight containers. Make sure they are placed in a cool, dry, shaded area. A refrigerated facility is ideal. Ensure that all containers are accurately labeled.

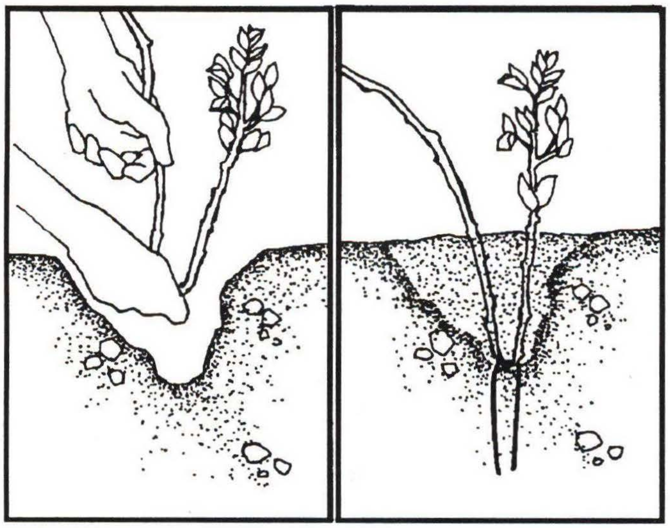
Seed bed establishment in the fall is most desirable because it allows indigenous seeds to follow seasonal preparation for growth—conditions impossible to duplicate off-site. Exposed sites will present unique problems of stabilizing the seed bed so that germination can take place. Rely on plastic mulching and naturalized landscape configuration to help compensate for this challenge!

3.2.8 Layering—Layering, or layerage, is a tried horticultural technique that allows the practitioner to reproduce, on-site, a limited number of shrub or woody plants that will be genetically identical to parent plants. This is a procedure at the experimental stage with many plants as a proactive backcountry technique.

The goal of layering is the formation of roots on a stem while it is still attached to a plant. The developing plant utilizes the nutrients and water from the parent plant as its roots develop. This new plant can be severed and transplanted to the restoration site or left as is, as an extension of a plant clump. If left connected to a parent plant that borders a restoration site, the new plant can reduce the size of the campsite or trail if bent into the area.

Simple layering is a basic technique and can be tried with a variety of multiple-stemmed shrubs, vines or trees. The system for simple layering is straightforward. Select a healthy lateral branch that is displaying new growth. Dig a trench about six inches deep and bend part of the branch into the ditch, leaving six to eight inches of leaves to the tip exposed. Remove any leafy material in the trench, scar or cut the bottom of the branch with a sharp tool, apply some rooting hormone (Root Tone, Homonex)

and refill using the richest soil available. Pin the layered branch down using a wooden or metal stake (coat hanger is ideal) before backfilling the hole and moisten. Lay mulch or a rock or both on top and flag the branch for future reference.



Layering technique

Flagging and date labeling the layered plant is vital so that it can be identified later. Place a metal nursery tag on the object plant with the date of layering embossed. Place some surveyor's flagging on the parent plant for quick reference the next year. Mapping the location on the Site Plan is useful. In keeping with wilderness ethics, remove the metal pinning stake after the layering is complete or use a wooden stake of native material that can be left permanently.

The season to initiate layering varies between different types of plants. With deciduous plants, simple layering can be done in the spring using long low branches produced during the previous growing season. Broad-leafed and needle-leafed evergreens can be layered during the growing season using shoots of current season growth. Do not sever rooted laterals of this type until the following spring.

Moderate success (50% rooting) has been achieved by this author at middle elevation areas in the Cascade Mountains utilizing Spirea, Willow and Salmonberry. Simple layering has also been successful on the low-growing evergreens such as Yew and Juniper (Larsen, 1979). Heather and Subalpine Fir have been observed to naturally layer themselves in extreme growing conditions at high elevations. Outlined below are 20 common Western plant species that have varieties which will respond to layering (Larsen, 1979).

Scientific name	**Timing**
Fraxinus sp.	spring, summer
Rhododendron sp.	spring, summer
Berberis sp.	spring
Vaccinium sp.	spring
Rubus sp.	summer
Betula sp.	spring, summer
Ceanothus sp.	spring, summer
Clematis sp.	spring, summer
Ribes sp.	spring
Cornus sp.	spring, summer
Sambucus sp.	spring
Calluna vulgaris	summer
Tsuga sp.	spring
Lonicera sp.	spring, summer
Juniperus sp.	summer
Kalmia latifolia	summer
Cercis sp.	spring
Rosa sp.	spring, summer
Salix sp.	spring

3.3 Site Management

3.3.1 Mulching—The introduction of native or commercial mulches is a valid way to compensate for environmental deficiencies in a restoration site. Properly applied mulches can inhibit erosion, retain moisture, protect plants and seeds, ameliorate surface temperatures, reduce frost action and provide some organic matter for soil build-up.

At sea level in temperate growing zones, mulching is almost always beneficial. In high-elevation, steep, alternately moist/arid restoration sites, mulching can be both useful and detrimental to the growing process. This section will discuss the pros and cons of natural mulching and commercial erosion control blankets in wildland restoration of remote areas.

Mulching is simply the application of a blanket or covering of native or commercially created material over a growing or eroded site. This is done after the installation of plants or the creation of a seed bed. The exception to this would be the introduction of organic native debris as an additive to a topsoil development program. These "soil mulches" which might include nearby humus, gravel, forest litter or woody debris, can help reconstitute and stabilize a site but serve a different purpose from common mulching.

Organic mulching requires the use of native material in and around a planting site. In a forested area, it is the naturally accruing litter layer. In open meadows or avalanche chutes, it may be a mass of decomposing herbaceous, leafy material. In the high alpine, it may even be loose rock or decomposing trees. It is part of the nutrient cycle in nature and provides habitat for insects and other organisms. A planting regimen that includes mulching will assist in elevating ground humidity and moisture retention during arid periods. Mulch can be gathered from nearby work sites or from accessible locations that have an abundance of decomposing material in the ground. Once again, restraint should be exercised in stripping an existing area of naturally accruing material.

The process of mulching begins by spreading harvested material 2-4" deep around the base and in between plantings. The material should not be pushed up around the crown or stem base of plants. Air circulation is needed in this area to prevent fungus damage. Bark, sawdust or other heavy, woody chips should not be used

exclusively. Research has demonstrated that woody material high in raw cellulose can leach existing nitrogen from soil particles, thereby robbing new plants of a vital nutrient (Bomke, 1980).

Several other precautions should be noted in the use of mulches. Caution should be exercised in their use in the development of seed beds in both high altitudes (5,500 ft. +) and cool, moist areas. Research is inconclusive as to the positive or detrimental affect of native mulches on seed germination in these two environments. Additionally, native mulches may decompose quickly, may need to be fastened to the ground in exposed terrain (with netting) and may not be available in adequate amounts nearby (Rochefort, 1990).

In general, mulching is most effective in assisting plant growth in microsites that receive high soil temperatures over a longer growing season. Areas such as those above timberline, krummholz zones and fellfields have short seed germination seasons and don't need the lowered surface temperatures that mulches provide. Sites that are naturally shaded, cool and moist may also not benefit from surface mulching.

The restoration site that would typically benefit from mulching might be as follows:

> *At 8,000 feet in the Lodgepole Pine zone in Yellowstone National Park is an average "established" backcountry campsite. It is located in a wooded area, near a small stream on nutrient poor soils derived from rhyolite. Use levels are around 50 people per season, each staying for an average of one night. There is a tradition of livestock use at the site.*
>
> *The decision has been made to close and rehabilitate the campsite. Transplants, seed bed development, relandscaping and mulching will be used. The elevation, length of growing season and partial tree canopy qualify this site as one that would benefit from surface mulching. The gradient is flat and wind protected so native mulch material from nearby sources will be used.*

The first choice for any remote site should be indigenous materials. This could include harvested leafy material, needles, duff, decomposing logs and even gravel. Unfortunately, these materials are not often available in adequate amounts and may need to be secured to the ground against the elements. Native mulches will decompose more rapidly than commercial mulches, but this can serve as a soil enrichment opportunity. Relying on indigenous mulches as a seed source can be counterproductive. A dry, lakeside site along Snow Lake in the Central Cascades was layered with locally collected snow-melt and pond slurry, seeded and covered with plastic. The next summer the plastic was lifted to reveal a healthy crop of pond bottom plants growing prolifically rather than plants from the desired plant community.

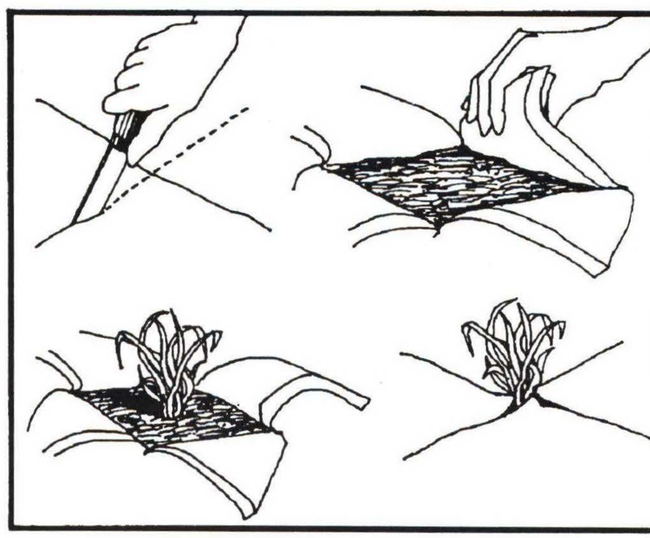
Commercial mulch mats are used extensively in the field and can provide similar, if not technically better and more efficient results than native mulches.

Manual seeding with desired species under a native mulch is not precluded. Seeding in conjunction with straw and hay mulches at roadside sites in Mount Rainier and Jaspar National Parks has proven to be effective. An application thickness of one to three inches is important for proper germination conditions. Wind loss and snow creep can also occur if light native mulches are not secured. It is not recommended that imported straw, hay and other grains/grasses be used for Wilderness restoration because of the possible introduction of domineering, non-native species.

3.3.2 Commercial Mulch Matting—Many restoration and erosion control projects in the mountainous West have benefitted from the introduction of commercially available "erosion control blankets." Normally, these products consist of a layer of organic material covered on one or both sides by a layer of polyethylene or polypropylene mesh netting. The poly-mesh is theoretically photodegradable. The material is unrolled, cut and spread over the restoration site, then anchored to the ground. The advantage of this material is that it:

1. Helps retain soil moisture
2. Helps reduce erosion by catching soil particles
3. Reduces compaction and erosion caused by raindrop impact
4. Adds organic material as it decomposes
5. Is visible, thus letting visitors know what is going on (Merigliano, 1990)

To this can be added the opportunity to stabilize transplants and seed beds through the use of mulch mats. It is recommended that seed beds under plastic be accompanied with commercial matting. This provides a more environmentally stable growing area for seedlings once they have become established. The plastic can be removed after one season allowing new plants to push up through the mulch mat as it decomposes. Transplants should be installed after the mat is laid out. Cut a cross 6-8" larger than the transplant wad. Peel it back, dig, plant, then fold the mulch back in around the base of the new plant.



How to install transplants in mulch matting

A major precaution in the use of many mulch blankets is the disposition of the poly-mesh that is utilized to hold the organic material together. The precaution that must

be noted is the impact of these hypothetically degradable materials on wildlife in the area. Reptiles and small birds have been shown to be vulnerable to potential entanglement and eventual death in the plastic mesh (Dice, 1990). In addition, elk, deer and fur-bearing animals passing through areas with a covering of this material rip and pull it thereby counteracting its effectiveness. This was evidenced in the use of Aspen Excelsior in the Tower Falls area of Yellowstone National Park. Wads of plastic mesh were found at the edges of rehabilitation sites on the lower trail after two years, the result of ungulate interference.

Heavy application of mulch matting

The recommended procedure is to lay out the mulch mat, then remove the plastic mesh by hand. Utilize rock and woody debris to hold down the organic mulch. Purchase a mulch that will bind itself together, such as Curlex or Excelsior, through the provision of long fibers. The exception to this would be when erosion control is the primary use of the mulch mat. Removing the mesh in this case would be counterproductive. Caution should be exercised in using coated mulches in these situations, balancing resource repair against wildlife preservation.

Table 3 outlines a summary of currently available mulching systems with evaluative information and 1990 prices, provided by Mount Rainier National Park.

3.3.3 Watering/Irrigation—One aspect of plant growth that is vital to the success or failure of on-site restoration is watering and moisture retention in new plants. Plant physiology requires the restorationist to continually consider the moisture needs of plant tissue, especially in newly installed plants. Water stress can lead to stomatal closure, reduced photosynthesis and die-back (Coleman, 1988). This variable needs to be integrated into the Restoration Plan.

Mountainous areas provide plant-growing challenges that accelerate with increases in elevation and exposure. Water temperature and radiation stress are factors in plant survival during both winter and summer. Add wind-induced drying, snow pack, frozen soil, erosion, diurnal temperature changes, short growing seasons and extended drought periods, and it seems a miracle that any living plant tissue can survive in mountainous regions.

All plants indigenous to a region have adapted to their particular microclimate. This is one of the primary justifications for collecting or propagating plant material that comes from a collection radius as close to the restoration site as possible. This will increase plant survival rates and reduce the amount of maintenance needed in a site after the restoration process begins. Proper site preparation, planting procedures and ongoing maintenance are aspects of plant management under the control of the restorationist.

Hypothetically, plants can be installed and managed at almost any time during the growing season or fall. Almost daily maintenance is needed though, during times of high moisture stress. This is ideal, but is generally impractical due to high labor costs. Middle elevation (3,500 ft.) plants were installed midsummer along the shore of Lake Dorothy in the North Central Cascades. Though shaded and generally drought-tolerant, these plants survived the warm season (and potential trampling) due to daily watering and maintenance by an on-site volunteer. Normal ranger presence in the area would have been weekly, which is not enough to maintain the plants during a high stress period.

Problems due to moisture loss can be minimized by fall planting, shading, mulching and the use of irrigation systems.

Fall planting is a timing technique that allows the restorationist to install plants just before the dormant season and in typically cooler, wetter weather. Days are shorter and ultraviolet stress is minimized. A rule of thumb for the restorationist is that lousy weather at the Ranger Station means good planting conditions in the mountains. One to two months before the winter snow pack begins to accumulate is adequate. This gives plants a chance to adapt and harden off for the winter when moisture stress is less of a factor. Greenhouse grown plants should not be directly transported from the growing area to the backcountry. They need to be preconditioned by living outside well before transplanting. This is done by moving plants outside under shadecloth or into a partially shaded area well before they are transported to the backcountry (1-2 months).

Good, deep root development on a plant is vital for plant survival. Soil preparation is the key to this process, but is probably the most challenging in the back country. In lieu of radical soil modification, mulching can assist in developing the growing environment. **Mulching** is utilized by conscientious gardeners and landscapers for weed control, insulation, stabilization and for our purposes, moisture retention.

Direct watering of installed plants will be necessary if work is taking place during the typical field season when plant survival is most threatened by high temperature, wind and drought. Working to the restorationist's advantage is the drought tolerance of many pioneer species plants that are typically used in revegetation projects. If properly transplanted, mulched and shaded, these plants will tolerate some neglect. Yet, there are few "no" water plants in the mountainous regions of the West, so

a watering system in conjunction with advantageous cultural growing conditions may need to be organized in the Restoration Plan.

Timing, frequency and availability of water are three variables that control a watering schedule. The time of day and depth of watering is important. Early morning watering works best for several reasons. Water transportation systems within plants and plant cell turgidity are typically most ready to absorb fluids in the cooler, calmer weather after sunrise. Less energy is being diverted to later day juggling of both photosynthesis and transpiration. Low humidity, calm wind, natural shading and low sun angles all contribute to the ability of plants to absorb water introduced in adequate quantities to the root system in the early morning.

There is no substitute for deep watering, even when done infrequently. Shallow watering encourages weed growth and distorted plant growth. Root systems gravitate toward water. Shallow watering will either miss the root system completely or force new roots to grow upward towards available moisture. This is counterproductive in solid root development. Elevated surface soil temperatures will dry out shallow root growth, and frost heave will dislodge poorly rooted plants in the winter. The best way to gauge deep watering is to use a commercially available moisture sensor or probe or make a visual observation of darkened soil around the crown of the plant. Several random plants can be selected and carefully probed manually for cooler, moister soil.

Double-watering requires an initial heavy application of water with a lighter, follow-up watering soon afterward to ensure saturation of the root zone. Allow drying between waterings if planting is in heavy clay soil. With good mulch and properly installed, healthy plants, watering frequency may be as low as twice per week. In exceptionally hot or windy weather, frequency may need to be increased to every other day. Once again, fall planting in cool, wet weather reduces the need for frequent watering.

Remember to form a basin around the base of the transplant, especially on steeper ground. With available water often at a premium, why watch water flow away from the planting site?

Soil that is highly compacted is relatively impermeable; water runs off rather than filtering into the soil. Permeability can be increased by loosening the soil and by introduction of organic matter into the top soil layer. Within practical limits, drainage of clay soils can be improved with surface scattering of lime or gypsum (calcium sulfate). Gypsum would be used in the typically high-sodium or "black alkali" soils of the Southwest. Acid-rich soils of the Northwest benefit from the introduction of lime.

Readily available water in adequate amounts is, of course, the great Western challenge. It is recommended that restoration sites away from water sources be outfitted with water storage and possible irrigation systems. The key is collection systems that gather and hold water when it is available. Typically, this is during spring snow melt and rain storms.

Holding containers need to be durable, simple and portable. In keeping with wilderness ethics, they should be temporary and as obscure as possible. Technology has provided us with inexpensive, sturdy plastic barrels that can be transported to backcountry sites with relative ease. Forest fire crews have a variety of water collection and storage devices that can be garnered by the restoration crews. Cisterns can be constructed out of simple plastic sheeting or other gravity-fed collection systems.

Whatever the reservoir system, it should be covered and relatively close to the restoration site. This is the advantage of barrels and bladders as opposed to many firefighting sump systems; they can be covered and protected.

Water storage systems that aren't covered, or can't replenish themselves, will become victims of evaporation or watering holes for animals. A water storage device can be combined with a drip irrigation system to provide plant-specific watering even without personnel in the area.

Drip irrigation systems are readily available in nursery and hardware stores. They have the capacity to deliver set amounts of water to specific areas through the use of light polyethylene tubing fitted with emitters or sprays. Tubing can be buried or placed on the soil surface. Though very water efficient, this system may be of limited use in remote areas because of the need for water pressure to drive the system. An interesting alternative is the use of perforated soaker hosing combined with a timed-
release valve and water storage system. A 50 ft. x $^5/_8$" soaker hose can selectively water up to 300 square feet using a recycled rubber tube with thousands of laser-drilled holes. The hose can be buried or surface mounted, is very weather resistant and is relatively inexpensive. The hose can be attached to a battery-driven timer and valve system that bleeds water from the base of the water storage device. The advantage of this is the ability to set the water control to allow for watering at optimal times even when personnel are away. The hose also does not require exceptional water pressure to make it function. The whole system can be set up for under $75.00 at 1991 prices. The prototype of this was set up at Snow Lake in the North Central Cascades and was used with moderate success by the North Bend, U.S.F.S. Ranger District in 1988. Operating this system at low pressure for long periods is the key to success. One inch of water delivered throughout the growing area will require as much as two hours of soaker hose operation.

Third world cultures in very arid areas of Northern Africa have discovered that terra cotta pots shaped like this can be buried up to their necks in extremely dry sites and, once filled with water, slowly seep water to the root systems of nearby melon plants. The buried pot does not transpire water to the air, and plants receive a slow supply of water to their root zones. This may be worth experimenting with in the maintenance of more deeply rooted transplants in the arid areas of the mountainous West.

Another device that delivers water directly to root systems of larger plants is the perforated P.V.C. pipe. One and $^1/_2$ to two inch pipe with holes drilled randomly in its side can be installed along with the transplant. Watering simply becomes a matter of filling the pipe with fluids and waiting for it to percolate down to the root zone.

This has been used very effectively by the author in both urban and highcountry transplant sites. It is easily removable after the plant is established.

In summary, fluid intake by new plants in mountainous terrain is vital for their vigor and longevity. A well-watered plant can resist insects and disease and devote energy toward new growth, not just survival. Factor in this cultural growing need of all introduced plants in the restoration site. Take advantage of seasonal resources and timing, mulching, natural shading and established watering techniques. Include contingencies for these in the Three-Year Restoration Plan.

3.3.4 Shading/Wind Barriers—A passive technique to reduce moisture loss is the installation of wind and sun screens. Transplants and seed beds on exposed ridges and open meadow sites are especially susceptible to desiccation. Though technically challenging, on-site efforts can be made to protect these new plantings.

In the nursery industry, **shade cloth** is often draped over greenhouse crops to reduce solar heating by up to 50% during the summer. Shade cloth is bulky, expensive and impractical in backcountry settings. It is useful for restoration projects near road access and protecting plants that are being held over near an agency facility in preparation for fall planting. Shade cloth is very durable and U.V. resistant, and will last for many years. Shade cloth needs to be suspended over a growing site, and it is not water permeable to the extent that it would allow consistent rain watering. Though considerably less frequent, a watering program would still need to be instituted in the dry season if utilizing shade cloth. The most practical approach to shading and wind protection is through naturalizing the growing site. As discussed earlier under landscape considerations, using a variety of plant materials and native features can promote culturally healthy growing conditions for plants. A nearby log, rock or taller plant will serve as a screening feature that protects tender plants. Observe rock islands and tree clumps for analogous examples of how nature supports plant growing in harsh climates.

Erosion control devices and mulches will also serve to provide shading.

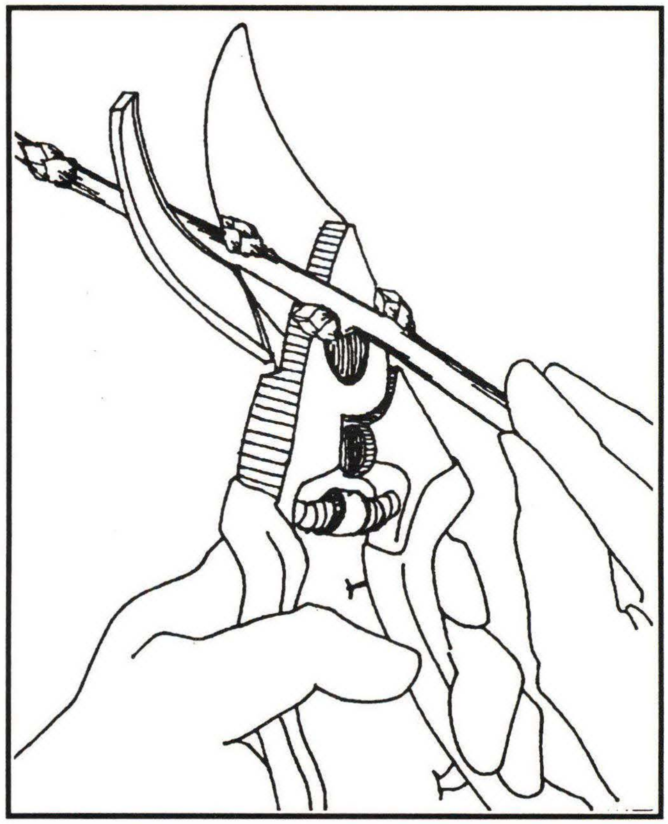
3.3.5 Selective Pruning—There are several subtle yet effective techniques for utilizing on-site plant material for several specific restoration activities. These procedures can be added to the repertoire of plant management approaches that have proved to be horticulturally sound. Wilderness ethics do require that this be done judiciously.

If the goal of the renovation project is to close out or obscure a campsite, trail or other created feature, then selective pruning of on-site woody plants can slowly assist in this process. Shading of newly introduced plants can also benefit from this process.

Pruning is an art based soundly on scientific principles. The physiology of plant growth is very predictable and can be manipulated by the restorationist. The primary advantage of this is the option of training existing plant material to grow in desired directions and density. If the plant material is available, then the practitioner can train branching systems into a trail corridor or campsite by stopping growth in one direction and encouraging it in another.

Ideal plants for this procedure include deciduous trees, such as Vine Maple and Elderberry; tall evergreen shrubs, such as Laurel and Huckleberry; medium evergreen shrubs, such as Salal and Heather; tall deciduous shrubs, such as Western Azalea and red/blue Huckleberry; and medium shrubs such as Gooseberry and Willow. Evergreen trees are not suitable due to their slow growth and upright growing form.

What most of these useful plants have in common is their spreading growth habit and easily identifiable buds and branches. By cutting above a bud or branch, all of the nutrients moving up a parent stem will be diverted into the direction of new buds or remaining plant growth. This allows the restorationist to guide growth in a desired direction.



Proper pruning angle above a lateral bud

A terminal bud grows at the tip of a stem. By severing this feature, growing energy will be diverted to lateral buds or stems. A lateral bud or stem grows on the sides of a primary stem. By cutting these, the primary stem will grow longer. Cutting directly above a lateral bud will force growth in the direction the bud is aiming. This procedure is more effective in newer growth areas on a plant (softwood), but can be effective if a latent bud in older wood is identified and pruned accordingly.

An interesting backcountry example of this principle at work can be seen in improperly brushed trails. Trail corridors that haven't been cut back far enough or were

sheared rather than pruned will refill with new growth much sooner than trail brushing maintenance standards call for. Conversely, if the goal were to close out a trail, then surface shearing or pruning of terminal stems would encourage bushier growth. Stems will also grow from the edges towards the open, sunnier, less competitive regions of a denuded restoration site, which helps the process.

The only tool necessary for this activity is a pair of hand pruning shears. One-hand hook and blade shears are preferable. They are relatively inexpensive ($7.00 to $30.00), easily transportable and straightforwardly sharpened.

Be discreet in making pruning cuts. Don't overcut any one plant, or leave unnatural looking stubs. Cutting plants near to dormancy is desirable but not usually convenient. Avoid the blooming stage of a plant; otherwise, most plants are durable enough to withstand a modest amount of pruning throughout the year. Use pruned branches for mulch or shading elsewhere.

3.4 THREE-YEAR RESTORATION PLAN SITE DESIGN/PROPAGATION CYCLES

ACTIVITY	YEAR I	YEAR II	YEAR III
Field Transplants *All plant varieties	Select appropriate plants and record	Move when weather is moist or irrigation is available	Monitor
Root Pruning *Woody shrubs and small trees	Root prune selected on-site stock in Spring/Fall	Root prune again **or** transplant in Fall	Transplant stock and monitor
Layering *Variety of deciduous and evergreen shrubs	Layer selected plants	Check for rooting and transplant Re-layer unrooted plants	Monitor transplants Transplant newly rooted plants
Root Division *Perennials and some shrubs	Select desired plant material and record	Divide desired plants and transplant	Monitor
Selective Pruning *Woody plants	Select and make initial cuts	Monitor and make follow-up	
Plant Recovery All plant varieties	Salvage available plants from nearby worksites and **hold over**	Continue salvage and transplant available material	Transplant and monitor
Soil Preparation	Analyze soil Stabilize with initial structures	Continue rehabilitation from soil source, mulching, etc. Continue stabilization with permanent structures and landscape features	Monitor and continue mulching
Composting	Select site - begin process	Continue process	Transfer composted material to planting site
Mulching, Natural	Identify nearby available material and record	Transfer mulch at end of site preparation and planting	Transfer extra material as needed
Mulching, Artificial	Assess need	Purchase and layout intial sections	Layout **or** remove sections as needed
Soil bank	Identify soil sources, haul and store	Integrate soil into site material	Continue as needed
Rock Structures	Identify available material and lay out in Site Plan	Move into restoration site before planting. Integrate with stabilization activities	Install final plantings and mulch around rock
Woody Structures	Identify available material and lay out in Site Plan	Move in and secure large pieces before planting	Lay out final pieces to obsure or shade site
Fertilization	N/A	Use selectively with transplants	Use selectively with transplants
Seed Bed	Select sites and record. Collect seeds and store	Layout seedbed after site preparation	Monitor bed and remove plastic a/n
Watering/Irrigation	Select watering system. Purchase equipment	Begin watering plan after installation. Install irrigation	Continue watering as needed. Remove irrigation devises if plants are well rooted and mulched
Shade and Wind Barriers	Integrate into Site Plan. Purchase materials	Install after plantings and site preparation	Remove if plants are well rooted and mulched
Solarization	Determine need and implement procedure	Follow-up as needed	

4.0 CONCLUSIONS—FUTURES

On-site restoration activities provide unique challenges and opportunities for the practitioner. Every denuded site designated for rehabilitation requires both specific and generalized skills and planning. Tent pads or social trails within a given lake basin may provide similar presenting problems but a view toward the niche ecology of each site will be required. The art and science of restoration is still in its infancy stage as a predictable paradigm for overall success. Mitigating factors, such as continued impacts and funding shortfalls, can undermine efforts already complicated by the innate resistance of damaged terrain to heal itself under the rudimentary tools of the restorationist.

Problems to be broached include public understanding, reliable sources for plant material, use of introduced soil amendments, ongoing site maintenance, non-native "weeds" or exotics in growing areas, genetic integrity and successional species issues. There is a need for more hard research to support investments in time and resources.

College-level and technical training programs are also needed to support research and to train the new generation of environmental restorationists. The fields of bioengineering, hydrology, soils, horticulture, landscaping, agriculture, forestry and land management can all contribute collective wisdom to efforts to heal the land. Experiments in soil/seed banks, irrigation systems, propagation of difficult plants and impact management are but a few emerging areas that hold promise for expanding the options for the remote site restorationist.

It is hoped that this publication will not only provide an introductory set of tools and techniques for on-site restoration, but will plant some seeds for future growth and development in this field.

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6.0 ADDENDA

6.1 Work Crew Organization

Ecological restoration is a long-term, often labor-intensive activity. Proactively rehabilitating a site requires planning, timing and a commitment to follow through for at least three years. Restoration is not an activity that responds directly to the amount of resources allocated to complete it. Large numbers of initial workers will not make the plants grow faster or keep them watered over time. Some restoration activities can be done conjointly, but most will need to be done in sequence over time.

The Three-Year Restoration Plan can be utilized as a guide for both managers and field workers. Specific planning and recordkeeping will need to be implemented by a manager who understands both restoration and the specific sites involved. Equipment and supply purchases, action plans, assignments and general coordination are tasks that the manager will need to monitor continually.

Much of the planning will resemble that which is done to gear up a trail crew to complete a backcountry project. Tools, transportation, food, camping, communication and personnel will need to be factored into work plans. Weather, catastrophic events, budget cuts, competition for seasonal field workers (read: fires) and agency turnover will mitigate the formula. Restoration in remote areas cannot be done casually or incidentally.

Crew size can vary according to the required task. Site preparation and stabilization is largely heavy physical work that a crew of four to six workers can implement. On-site propagation and site maintenance can be completed by lesser numbers of workers with specific skills, such as plant identification and nursery experience. Fewer workers over time will reduce secondary damage to the restoration site. Heavy lifting, inclement weather, tool usage and work in remote locations will be considerations when allocating human resources to the restoration job. Once again, the scale of any project and the resources available will determine distributions of time and effort.

6.2 Tools and Materials for On-site Restoration Practices

Like other resource management activities, restoration requires basic equipment and materials for implementation. Many of these materials and tools are available through forestry catalogs or can be found in typical agency tool caches.

Other specialty tools and consumable materials will need to be solicited from nursery catalogs and local/regional supply houses. The restoration library should include a broad selection of updated references, names of representatives and catalogs.

A storage area for supplies should be established and maintained. As with other tool-dependant work tasks, equipment should be cleaned, sharpened and repaired on an ongoing basis. Materials need to be ordered and stockpiled well before the field season. The THREE-YEAR RESTORATION PLAN should include references to material orders and tool acquisition.

A basic tool and material list is included below. Regional differences and personal preference may alter the list of needed implements. Prices are not included, but it is assumed that the standard of quality for restoration tools will be the same as for other agency purchases.

TOOL	ACTIVITY
Scoop Shovels	General
Tree Spades	Root pruning, transplanting, root division
Plastic Buckets	General
Hand Trowels	Transplanting, layering
Soil Cultivators	Scarifying soil, site preparation
Hand Pruners	Selective pruning, transplants
Pulaski	Site preparation, landscaping
Mallet	General
McCleod or Rake	Mulching, landscaping
Rock Bar	Landscaping, site preparation
Soil Thermometer	Seedbed

6.3 Typical Supplies and Materials

SUPPLIES	ACTIVITIES
Rooting Hormone	Layering, cuttings
4 mil plastic	Seedbed development, Solarization
Liquid Fertilizer with Vitamin B	Transplanting, general application
Transplant Shock Fluid (Upstart)	Transplanting
Stakes, Flagging	Root pruning, layering
Nursery Tags	Root pruning, layering
Ziplock bags, Paper lunch bags, sharp cutting tool	Seed collection
Artificial Mulch Matting	Mulching, site stabilization
Irrigation Equipment	Site maintenance
PH and Soil Testing Kits	Site preparation
Shade Cloth	Plant Protection, propagation

6.4 Case Studies

6.4.1 GREEN MOUNTAIN: NORTH CENTRAL CASCADES

by

Russ Hanbey

Green Mountain is an extensively meadowed peak that rises 6,500 ft. above the Suiattle River to connect with Mount Buckindy in the North Central Cascade Mountains in Washington State. Fifty percent of the steeply ridged peak lies within the Glacier Peak Wilderness area. There is a historically significant fire lookout atop the mountain that is accessible via a four-mile climb. The trail rises through a subalpine vegetation system that is attractive to hiker and hunter alike.

Many plant communities are represented in the area, including the Subalpine Fir/Sitka valerian collective. The summit trail passes a small lake and narrows as it ascends sharply through the Heather-Huckleberry community. Isolated campsites, a U.S.F.S. helipad and old shed site are spaced along the narrow summit ridge to the lookout.

The etiology of present problems is related to a long history of human and stock impact, including up to 3,000 visitors per season in the 1980's. Restoration of the summit ridge was complicated by long distance from the trailhead, exposure to exceptional weather, steep aspect and location within a Wilderness area. The goals of the restoration efforts that began in 1983 were to close-out and repair a vertical "short-cut" trail down the summit ridge and restore the denuded helipad and shed sites.

The temporal activity was to restrict human usage of these areas. A sign was posted at the trailhead explaining the thrust of the restoration effort and asking people to restrict their camping to the lake basin below the summit ridge. The shed and helipad site were set off with string and signs. Low wooden barriers were placed at the ingress/egress points where the "short-cut" trail crossed the main trail. All of these efforts proved effective in diverting usage away from impact areas. Weather and marmots required resetting of the barriers each year.

The following techniques were used in the 30-45% gradient, rutted trail which was approximately 200' long in ten different sections. Most stretches were 1'-2' wide and 6"-12" deep.

1. Soil was "tilled" or loosened.
2. Plugs of nearby sod were placed at 10' intervals through 124' of the trail.
3. Rock/wood check dams were installed below each plug.
4. Plugs were watered, using chunks of snow placed above each plug to drip below.
5. Jute netting was laid over each section that included transplant plugs (124").
6. Rocks were installed in 60 remaining feet imitating nearby rock/soil patterns and allowing it to naturalize.

The status of the plugs in 1985 and 1987 was assessed and 83% were maintaining or thriving. The following plants were doing well within the plugs or were spreading inward from the trail berm:

Polygonum bistortordes-common Bistort, Potentilla flabellifolia-Fanleaf cinquefoil, Vaccinium deliciosium-Cascade Huckleberry, Luetkea pectinata-Partridge-foot, Polemonium, sp.-Jacobs ladder, Care nigricans-Black sedge, Alpine Timothy, Veronica wormskyoldii-Alpine Speedwell, Pedicularis sp.-Lousewarts, Lupinus lepidus-Alpine Lupine, Phlox diffusa-Spreading Phlox.

GENERAL OBSERVATIONS

a. Jute netting unravelled, but was not decomposing. It became entangled with emerging plants and was difficult to remove.

b. Little or no naturalizing of plants in trail ruts over 6" deep and less than 24" wide. Wider, shallower ruts demonstrated much better volunteer plant growth.

c. Plugs were effective, but behaved like "islands" with little growth beyond their perimeters.

d. Natural shading using landscape techniques would have been useful.

e. Plugs removed from near the restoration corridor created new divots and denuded spots of their own.

f. Remoteness of area lead to sporadic maintenance and watering.

Shed and Helipad Sites

In 1985/86 both sites were prepared for restoration, having been closed off in 1983. A rock path was installed through the shed site in order to channel the multitude of people who pass through it on the way to the summit. Rocks were installed in the open areas mimicking nearby rock patterns. Organic debris was spread on the helipad site, the soil was loosened and nearby seed was scattered. 250 cuttings of Luetkea pectinata were collected along with 20 small plugs of Alpine Timothy and Black Sedge. Seeds from Mountain Ash, Huckleberry, Alpine Timothy and Black Sedge were collected. All of these live materials were taken to Shorecrest High School in North Seattle for propagation activities.

The greenhouse program was successful in growing sedge and grass from seed and performing root divisions from plugs of the same species. Luetkea was successfully rooted but died two months later. No germination of Ash and Huckleberry was noted.

Plants were backpacked to the summit ridge in 1986 and 1987 and installed in both sites. Marmot hole tailings material was used, along with B-1 Upstart as a nutrient base. In 1991, 90% of all plants were observed to be thriving despite three years of exceptional drought. New plants were slowly naturalizing in each area, including Fireweed, Bistort, Luetkea and Jacobs Ladder.

Conclusions

1. An off-site propagation program is needed for restoration of areas that provide very limited nearby plant material.
2. Diverting people and stock away from work areas is vital (along with education).
3. Volunteers are a valuable resource. 90% of the work on this project was done by volunteers.
4. Restoration in remote wilderness areas provides tremendous transportation and plant maintenance challenges.
5. Nearby resources, such as Marmot tailings and rock, can be judiciously used.
6. Rutted trails need to be back-filled before planting or naturalizing.
7. Jute is counterproductive as a restoration tool.

Sidenote 1991

In the Winter of 1991, the western slopes of the Cascade Mountains experienced several exceptional storms followed by warming trends. Because of this, access to Green Mountain was essentially cutoff to the public due to road washouts.

Additionally, the spring/summer weather patterns presented a mixture of rain and sun that promoted extraordinary plant growth in the subalpine. The virtual elimination of people and favorable growing conditions has led to remarkable regrowth along the lower trail corridor and summit ridge. Plants such as Alpine Willow-Herb (epilobium alpinum), Bistort, Lupine, Huckleberry, Bracken Fern, Fireweed and several clumping grasses have flourished in the trail pads.

This is a testimonial to the growing energy of plant matter and the process of naturalization of undisturbed sites. Without human intervention the damaged areas on the summit ridge would not have had the foundation for regrowth within our generation. Both strategies are worthy of merit.

Suggested Information Signs for Green Mountain

Trailhead Informational Sign—Laminate or reproduce on hard plastic place in obvious, high profile spot up the trail from the trailhead sign.

GREEN MOUNTAIN IS RECOGNIZED THROUGHOUT THE NORTHWEST AS AN AREA OF UNIQUE BEAUTY AND NATURAL DIVERSITY. IT LIES WITHIN THE GLACIER PEAK WILDERNESS AND IS UNDER CONSIDERATION AS A NATURAL PRESERVE UNDER THE STATE OF WASHINGTON NATURAL HERITAGE PLAN. MANY BIOTIC ZONES THRIVE ON GREEN MOUNTAIN, WITH SPECIAL REPRESENTATION OF THE SUBALPINE FIR/SITKA VALERIAN PLANT COMMUNITY WITHIN THE MOUNTAIN HEMLOCK ZONE.

IN ORDER TO PRESERVE THE DELICATE BEAUTY OF THIS AREA, RESTORATION WORK IS TAKING PLACE ON THE SUMMIT RIDGE BY VOLUNTEERS AND U.S.F.S. PERSONNEL. PLEASE HELP BY NOT CAMPING ABOVE THE LAKE BASIN AND BY STAYING ON ESTABLISHED TRAILS.

THANK YOU

Summit Ridge Informational Sign—To be placed above lake basin or at the base of the summit ridge. Made of durable material, obvious but low profile.

WILDERNESS RESTORATION SITE

WE REQUEST YOUR ASSISTANCE IN HELPING RESTORE THIS AREA TO ITS NATURAL STATE. PLEASE DO NOT CAMP OR ESTABLISH FIRES ABOVE THIS POINT. PLEASE STAY ON THE PRIMARY TRAIL. CAMPSITES ARE AVAILABLE IN THE LAKE BASIN AREA.

THANK YOU

6.4.2 PARADISE MEADOW RESTORATION: MOUNT RAINIER NATIONAL PARK

by

Regina Rochefort

Paradise is a heavily used subalpine meadow in Mount Rainier National Park. The area is a popular destination for day hikers and is the primary approach for ascent of the mountain. Heavily used since the early 1900's, the area today receives over 1.08 million visitors annually. Over 70% of park visitors select Paradise as their primary destination.

The meadow encompasses approximately 389 hectares and extends from 1,646 to 2, 256 m. in elevation. Park policy is to discourage off-trail hiking due to the fragility of the subalpine vegetation, but off-trail travel does still occur, causing new impacts and perpetuating existing bare-ground impacts. Today there are 913 human-caused, bare-ground impacts in the meadow.

Many of the the impacts visible today have resulted from activities no longer permitted in the meadows: a tent camp (1890-1930's), horse concession (1908-1965), golf course (1931) and ski concession (1934-1975). Horse travel resulted in trails 2-4 m. wide and up to 0.3 m. deep. Tent platforms and roads from the tent camps are vegetated but still remain below grade and are easily recognized by topographic or vegetation differences from adjacent areas.

Impacts created in the last 20 years are primarily social trails and rest areas caused by foot traffic rather than the early recreational impacts made by heavy equipment or stock animals. Recent impacts are located at higher elevations in heath-shrub communities that are not very resilient to human use. Most of the impacts that originated in the early 1900's developed in the more resilient lower meadow sedge or lush herbaceous communities.

Restoration in the Paradise area probably began around 1937 in conjunction with construction of the Stevens Canyon road. At that time, a half-mile perimeter around the current Paradise upper parking lot was denuded. Civilian Conservation Corps workers were instructed to salvage plants from the future roadbed and replant them in the denuded area surrounding the parking lot. In the late 1950's the Park decided the best option for protecting the area was to harden (asphalt) the most severely eroded used trails. Today the meadow supports a maintained trail system that includes 16 trails with a total length of 21.7 km. Trails in the lower central area of the meadow still have asphalt surfaces, but most trails are rock lined with gravel surfaces.

Approximately 89% of the impacts are "social trails"—linear bare-ground impacts resulting from shortcutting between designated trails or connecting designated trails with points of interest. The remaining impacts (11%) are large bare-ground or trampled areas which are used as rest areas and/or viewpoints. Dimensions of the impacts are varied: lengths range from 0.5-1,500 m., widths from 0.1-25.6 m., and depths from 0.1-0.95 m. The total length of all human-caused impacts is 46.4 km., surface area is 4.8 ha. In 1986 the Park initiated a large scale program to repair human-caused impacts in the meadow. The first step of the program was to form an interdivisional committee to write a plan for protection and restoration of the meadow (Rochefort, 1989). The plan was developed over a three year period. Steps in plan development included field surveys of impacts, sociologic surveys regarding non-compliance and optimal control methods (Johnson and Swearingen, 1988), and development of a method to rate and rank impacts for restoration.

RESTORATION METHODS

Restoration of individual impacts involves six steps: scarification, stabilization, filling, revegetation, site protection, and monitoring (Rochefort, 1990). Many sites have become compacted and must be scarified to enhance root penetration and water percolation. Sites are scarified to depths of 10-15 cm. with a pulaski or rake and then individual soil clods are broken up by hand to small particles. Impacts which are deeper than three cm. require stabilization to impede downhill movement of soil. Wood or rock silt bars are installed as subsurface erosion control structures.

Following stabilization, the site is filled to the grade of the adjacent undisturbed area. Contouring the site is one of the most difficult steps of stabilization. Careful attention must be paid to the topography and drainage patterns of the immediate site so that surface flow or small creeks are restored to their original position. Fill material consists of three components: rock, gravel, and topsoil. Topsoil is used to fill the upper 0-15 cm. of each impact since most rooting occurs in this zone. Gravel and rock are used below the soil layer. Rock is used only on impacts deeper than 45 cm. to add stability to the site. All topsoil is purchased from outside the park but specifications require it to be approximately the same soil texture, pH, and organic matter content as that of native soils. Soil is steam sterilized to prevent importation of exotic seeds.

Once the site has been filled to grade, it is revegetated. Our goal is to revegetate the site with the community which would have been on site had there been no disturbance. Three revegetation techniques are used: seeding, transplanting, and natural revegetation. Most sites in Paradise are seeded and planted rather than allowed to revegetate solely by natural means. The growing season at Paradise is typically only 30-60 days. The short growing season, coupled with heavy visitation, leaves natural revegetation techniques at a severe disadvantage in this area. Restored sites are seeded and planted with native materials in September, just before the winter snows, to

minimize the need for watering. All seeds are collected as close to the impacted site as possible to maintain the genetic integrity of the site. Transplants are either salvaged from within the impacted site prior to filling or grown in the park's greenhouse from seeds or plant stock collected close to the impacted site.

The park's greenhouse is small (26.8 m.), but has produced up to 16,000 plants annually (1991 production figures). Currently the greenhouse grows 38 subalpine species and 13 species from lower elevation forested areas. Plants are grown from seeds, cuttings or vegetative divisions. Our most recent success has been the ability to propagate heather (*Phyllococe glanduliflora, P. empetriformes, Cassiope mertensiana, Empetrum nigrum*) and successfully outplant one year old transplants (planted in 1990). Plant materials are also produced off-site by the Soil Conservation Service's Plant Materials Center in Corvallis, Oregon. The Plant Materials Center is producing seeds and plugs of three common grass or sedge species. Revegetated sites are covered with an excelsior mulch to modify surface temperatures, conserve moisture, and impede surface erosion. Permanent revegetation plots established in 1985 have recorded transplant survival rates of 94% and average rates of spread of 230%.

Restored sites are qualitatively monitored annually and protected by barriers or signs. Selected areas are also monitored quantitatively with permanent vegetation plots. Meadow roves by park naturalists and nearby revegetation crews also protect sites by answering questions of curious park visitors.

One of our major difficulties has been the transportation of materials to sites. Most restoration sites are located 1.6-3 km. and 457-609 m. higher in elevation than the supply delivery site. Although seeds are light enough to carry to the site, fill material weighs an average of 2,000 lb/yd—an impossible task for human transport. The park has relied on helicopters to transport all materials to the site. Fortunately, military training missions have been available for a large percentage of transportation needs during the past two years.

Restoration has been completed on 35 social trails and partially completed on 24. This work has required 714 yds. of soil, 236 yds. of gravel, 143 yds of rock, and 29,150 greenhouse and/or salvaged plants. Our work is continuing at a steady, increasing pace as we learn from our past experiences and are encouraged by our past successes.

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6.4.3 INTEGRATING SITE REVEGETATION WITHIN A LIMITED BUDGET: AN INTERMOUNTAIN WEST CASE STUDY

by

Linda Merigiano

Very few wilderness programs can afford to establish an extensive program devoted to site revegetation. Usually, a wilderness program is not well funded, having few field personnel and only small, localized areas which could benefit from revegetation. Revegetation can still be part of these programs but rather than standing alone, it must be integrated as a secondary objective of some larger project.

This paper describes four examples where revegetation was accomplished as part of a larger project. All examples are from the Jedediah Smith Wilderness located in the Greater Yellowstone Ecosystem on the West Slope of the Tetons in Wyoming. Site elevations ranged from 7000 to 9550 feet. The higher elevation sites were located in subalpine granitic lake basins with scattered whitebark pine and subalpine fir with a ground cover of rushes (*Juncus drummondii* and *Luzula hitchcocki*) and numerous forbs. The lower elevation sites were located in limestone canyons with Engelmann spruce, subalpine fir and Douglas-fir with a ground cover of tall forbs.

EXAMPLES

As part of their job, wilderness rangers spend a fair amount of time dismantling fire rings located too close to lakeshores or streams or built where campfires are prohibited. Typically, the ashes and rocks are scattered, and the fire site is covered with duff. However, in open meadows, these devegetated sites can persist for many years. Furthermore, using needle duff may actually hinder reestablishment of the original species due to differences in pH between forest and meadow soils.

The Alaska Basin area is a subalpine granitic lake basin at an elevation of 9500 feet. The area was closed to campfires in 1979 due to scarcity of firewood and heavy recreation use. While the primary objective of the wilderness ranger job was visitor contact and education, rangers had an additional job to "naturalize" campfire scars. Some fire rings were simply dismantled or covered with rock.

Today, fire rings destroyed in this manner are still somewhat evident. Thus, in areas where a fire site was surrounded by meadow, rangers began incorporating revegetation into naturalization. The ashes and rocks were scattered, the underlying soil was loosened, pocket gopher "tailings" were added, and a few plugs of plants were transplanted. *Juncus drummondii* was commonly used, as it is easy to transplant and survives well. The site was then watered thoroughly. The end result is a site that blends well with the surrounding meadow. Except for a few cases where the fire ring was re-built, these sites have revegetated well.

Volunteer groups provide a large, enthusiastic crew for completing revegetation projects as part of other projects. Twenty people on the Sierra Club Service Trip volunteered to complete a Wilderness service project between August 19 and 24, 1988. The primary objective was to reconstruct approximately one mile of trail in the Green Lakes area. Revegetation of four campsites was integrated into the project as a secondary objective. Three sites were located on the shore of Green Lake, and one site was located on the shore of the lowest Granite Basin lake.

The sites had a long history of use, with large devegetated areas and compacted soil. One site was on a slope and was eroding even though visitors no longer frequently camped there. Fire rings were destroyed and the soil was dug up with pulaskis to a six inch depth. Twenty four log checkdams were installed to control sheet erosion across the sites. Aspen excelsior matting was placed over the sites and log debris was scattered over the sites to hold the matting down and to provide microsites for the plants. No metal stakes were used. Signs were installed at each site informing visitors that the site was closed for revegetation. 160 plugs of plants were transplanted. Species included *Juncus drummondii, Luzula hitchcocki, Erigeron* spp., *Vaccinium scoparium, Deschampsia cespitosa* and *Fragaria* spp.

Volunteers were given a brief demonstration on transplanting techniques. The plugs were watered every day for one week. The summer of 1988 was extremely dry in the Greater Yellowstone Ecosystem. Significant rainfall did not occur until mid-September. In October 1989, survival of the transplants was evaluated. Overall, 68% of the transplants were alive, 18% had died back, and 13% had died. Survival was highest for *Erigeron, Juncus* and *Luzula*. By 1991, the aspen excelsior was not visible; however, the green plastic netting covering the aspen had not decomposed and had to be removed.

An example of very effective integration of revegetation into other projects is when trail construction can be combined with trail restoration. In August 1989, the Sierra Club Service Group again volunteered to complete a service project. The primary objective was to relocate approximately one mile of trail away from the lakeshore in Granite Basin so that the trail would be located on more well-drained soils on a less steep grade and so that visitors would be encouraged to camp away from the lakeshore.

The trail construction site was in an open subalpine meadow with scattered clumps of whitebark pine and subalpine fir along the edge of the meadow. Typically,

abandoned trails are closed by covering the trail with log debris or rocks and letting the trail revegetate naturally. However, in a large meadow, this method of closure does not blend in with the surroundings, and the result is a string of logs or rocks which are apparent for many years. Thus, for this project, half of the crew constructed trail while the other half prepared the old trail for replanting and carried pieces of sod dug up by the construction crew over the old trail.

Transplants were watered initially, and the arrival of an early snowstorm provided considerable moisture. The dominant plant in the meadow was dense clumps of *Juncus drummondii.* The natural appearance of the meadow is dense clumps of *Juncus* with bare soil in between the clumps. With the random placement of transplanted clumps of *Juncus* in the old trail, it was nearly impossible to distinguish where the old trail had been at the end of the project. There was no need for signs to re-direct visitors. Survival of the transplants has been excellent.

A popular attraction in South Darby Canyon is the Wind Cave. A trail leads to the base of the cave but access to the entrance is 1/4-mile up a hillside with slopes of 80%. There has never been a constructed trail up this hillside, but over the years more than ten separate trails developed as visitors scrambled up the hill. Some of these trails had eroded two feet deep.

In 1991, trail funding became available for construction of a trail on this hillside. Soil and water funding had been requested for revegetation of the hillside but was not available. Thus, the primary objective was to construct a trail suitable for hikers that would concentrate people on one durable route.

Forest Service crews completed initial construction of the trail. A biology professor at Ricks College in Rexburg, Idaho was looking for an opportunity to have his natural resource students participate in some hands-on work experience and learn about wilderness management. In September, his class of 12 spent three days helping with the Wind Cave project.

Work during the day was combined with evening discussion around the campfire on wilderness living, values and management. The class completed the finishing touches on the trail construction and installed a hitchrack at the base of the hillside with a sign to let horse riders know that the trail was not designed for horse use.

However, much of the students' time was spent covering the old, eroded routes up the hillside with jute matting and log debris. The hillside was located at 8800 feet on a north-facing aspect with Douglas-fir, Engelmann spruce and subalpine fir. Jute matting was chosen over aspen excelsior primarily because the old routes required long-term stabilization and the moisture on the site suggested that aspen excelsior would decompose before the site was completely stabilized.

Signs were installed to prevent visitors from using the old routes where new trail crossed these routes. Transplants were not used nor was any seeding done. Given the productivity of the site, it is anticipated that the site will naturally revegetate quickly once erosion is controlled. It is too early to assess whether this effort has been successful.

RECOMMENDATIONS

All these examples show that revegetation can be accomplished without special funding by integrating it in with existing duties and enlisting volunteer help. These examples focus on campsite and trail revegetation; however, these are not the only areas where revegetation can be incorporated. For example, fire suppression activities are increasingly incorporating rehabilitation. To successfully incorporate revegetation, I offer the following recommendations:

1. Design projects to incorporate revegetation as the project is being done. This applies especially to trail construction projects where plants that are dug up provide a ready source for revegetation of the old trails. Even if plants cannot be used right away, they can be stored for short periods of time in cool, moist locations for later use.
2. Enlist the help of volunteer groups for revegetation efforts. It is important to choose projects that are appropriate for the group. Some groups do not have the patience for or interest in revegetation. The end result is dead plants and dissatisfied volunteers. Some hands-on instruction and demonstration is important to ensure high quality revegetation efforts.
3. Strive to break down the barriers between different job titles. The classic example is trail crew members who believe that revegetation is the job of the wilderness ranger. Design projects and provide training so that one crew understands the entire project and can successfully complete it.

6.4.4 PRELIMINARY RESULTS OF THE REVEGETATION OF A PACIFIC SILVER FIR PLANT COMMUNITY AT LOST LAKE, OREGON

by

Kevin Slagle and
Mark Griswold Wilson

The Lost Lake project is a four-year recreation area rehabilitation and expansion begun in 1990. Lost Lake is at 3,140' elevation just east of the crest of the Cascade Range and has been used as a campground since 1900; it receives 160" of precipitation a year, most as snow. The soil depth varies from 18"-36" above an impervious layer of cemented mudflow. Water moves through the soil from surrounding ridgetops to the lake, and no streams are present in the area. 133 campsites and 32 day use sites are being built/rebuilt along with over three miles of road. Revegetation work is integrated as a continuous process during construction because the site is generally only accessible from early May through late October. Approximately five acres of ground disturbed by construction is revegetated each year.

Plant community information from the publication "Plant Association and Management Guide for the Pacific Silver Fir Zone" (Hemstrom, et al, 1986) identifies four distinct Pacific Silver Fir (*Abies amabilis*) (ABAM) subcommunities within the project boundaries that range from hydric to xeric: Devil's Club (*Oplopanax horridum*), Foam Flower (*Tiarella unifloliata*), Alaska Huckleberry (*Vaccinium alaskense*), and Pacific Rhododendron (*Rhododendrun macrophyllum*). The project site plan, vegetation management plan and revegetation specifications were all developed using characterizations of the vegetative, environmental and soil data from the Management Guide. During the 1990 and 1991 seasons new road and campground construction has been in the drier huckleberry and rhododendron communities; 1993 work will focus on closing and revegetating many of the campsites in the wet and compacted foamflower and devil's club zones near the lakeshore (see figure 1).

Plant succession field data collected from adjacent clear cuts is used to determine the desired species composition and spacing for replanting. Forest Service staff and the independent horticulture consultant plan all work by preparing revegetation specifications and requirements in the construction contract; then, alternative service crews, temporary employees and volunteers are trained to carry out plant salvage, seed collection and propagation tasks. The revegetation project goals are: (1) Minimize construction clearing zones/maximize plant material salvage within clearing zone, (2) Replant all disturbed areas using plant material propagules collected only from on-site or adjacent clear cuts, (3) Protect the plant species integrity of existing ABAM subcommunities.

PLANT SALVAGE

In the early spring, before road construction begins, most plant materials within the construction zone are salvaged using either of two methods: direct transplanting or temporary storage. Four to six inch thick mats of pioneer grasses/forbs are dug up and directly transplanted in high impact areas such as steep slopes and pathsides. Slower growing trees, shrubs and forb clumps are balled and burlaped or placed in nursery flats and temporarily stored in capillary beds (shallow wading pool-like structures constructed of plastic sheeting and 2 x 8's and placed in full shade).

ROAD CONSTRUCTION/SOIL SEEDBANK SALVAGE

We conduct several reviews with all project team members throughout the construction season in order to determine the following season's road and campsite clearing limits. Where roads cross wet areas or may impact groundwater, we design "floating" roads by first flush cutting tree stumps and vegetation, then laying geotextile fabric over the undisturbed ground, spreading clean 3" minus rock topped with finer graded gravel and finishing with asphalt. On drier sites, a track-mounted excavator (Cat 225 size) removes the seedbank duff and topsoil inside the clearing limits; it is then hauled off-site and stored in small piles to avoid heating. After road paving has been completed, a medium-sized excavator (Kubota 191) and a bobcat loader redistribute the soil seedbank prior to planting and seeding with salvaged and/or nursery propagated plant materials.

In 1989 salvaged soil samples were "grown out" in a greenhouse in order to determine the species composition of the seedbank. No exotic species were identified in the samples, and most herbaceous and woody plants sprouted over a one-year period (see figure 1). Put into practice on the site, seedbank salvage results have, thus far, been less satisfactory; only the asterisk species in figure 3 have sprouted from the seedbank in the one year period since fall, 1990. During the 1991 construction season, a weed cutter was used to mow off the top of all vegetation in the soil salvage areas in the hope of increasing the survival of root propagules during storage.

WOODY PLANT PROPAGATION

Three species of woody shrubs dominate the understory of the ABAM community: Pacific Rhododendron (*Rhododendron macrophyllum*), Alaska Huckleberry (*Vaccinium alaskense*), and Oval-leaf Huckleberry (*Vaccinium ovalifolium*). Because of the matted, rhizomatous nature of the their roots, it has not been possible to salvage these species; therefore, a contract propagation program using site-collected cuttings and seed has been started at several nearby nurseries. During the first project year (1990) both Huckleberry species were collected as hardwood cuttings from January through March; they were lightly wounded, then stuck in a 1:1 coarse peat/perlite media and placed on a cool (65 degree) greenhouse propagation table and infrequently misted. Fifty percent of each huckleberry species successfully rooted. Rhododendron cuttings taken as semi-hardwood cuttings in late August through October of the same year and treated similarly were a failure with less than 1% rooting. Seed propagation of all these species was initiated in 1989 also and has proven very successful with greater than 80% germination; fungus infections, however, are a constant problem requiring exacting watering techniques and the use of fungicides after the seedlings reach the first leaf stage. Choice of seed-growing media has proven important; a layered mix with coarse sand on the bottom and fine peat on the top of the seeding flat (or cell pack) has worked best for all the ericaceous species. Inoculation of the soil media with mychorrizae-enriched forest duff collected from the project site has reduced seedling mortality somewhat and speeded growth.

Other woody deciduous species found on the site are propagated as in situ hardwood cuttings collected and placed the same day. Results have been variable, ranging from the 90% rooting of the Willow and Poplar *(Salix & Populus)* to the less than 30% rooting of Alder *(Alnus sinuata)*. Other woody species are only able to be propagated from seed which is collected and then taken to a contract nursery grower.

HERBACEOUS PLANT PROPAGATION

On-site seed collection of herbaceous species has been carried out each season since 1989 by Forest Service crews trained by the horticulture consultant; a particular emphasis has been put on the collection of pioneer species. Seeds are cleaned, dried and mixed according to the particular species composition of the four ABAM subcommunities where they are seeded. Two seeding methods have been tried: hand seeding in 1990 and contracted hydroseeding in 1991. Hand seeding produced very uneven results; over four inches of rain fell the day after the seeding, washing away the straw mulch. The pioneer grass/forb seed mix sprouted very slowly and did not provide any slope cover until mid-summer 1991. The hydroseed wood fiber mulch used in 1991 included the same pioneer grass/forb mix in addition to pre-germinated annual barley, pioneer shrub species seed and 60 lb/acre of tacifier in order to provide cover the first season after seeding. It is anticipated that the nurse crop barley will drop out after the first year.

ADDITIONAL INFORMATION

The Lost Lake Revegetation Project is on-going. The preliminary results above are from the first year of project work (1990-91). Additional project updates will be prepared yearly. For additional information please contact the authors: Kevin Slagle, Forester, Mount Hood National Forest, 6780 Highway 35, Mount Hood, Oregon 97041, (503)-352-6002; Mark Griswold Wilson, Independent Horticulture Consultant, 980 Southwest Broadway Drive, Portland, Oregon 97201-3108, (503)-222-0134.

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REVEGETATION LISTS FOR LOST LAKE PROJECT

PLANTS SALVAGED FROM CONSTRUCTION CLEARING ZONES:

- Abies procera (Noble Fir)
- Gaultheria ovatifolia (Oval Leaf Salal)
- Pseudotsuga menziesii (Douglas Fir)
- Rhododendron macrophyllum (Western Rhododendron)
- Thuja plicata (Western Red Cedar)
- Vacinnium alaskense (Alaska Huckleberry)
- Vacinnium ovalifolium (Oval Leaf Huckleberry)
- Xerophyllum tenax (Beargrass)

SAVED SOIL SEED BANK:

HERBACEOUS SEED & PROPAGULES-

- Achlys triphylla (Vanilla Leaf)*
- Anaphalis sp. (Pearly Everlasting)
- Carex sps. (Sedges)*
- Clintonia uniflora (Queencup Beadlily)*
- Cornus canadensis (Bunchberry)*
- Disporum hookeri (Fairybells)
- Epilobium sps. (Fireweed)
- Festuca occidentalis (Western Fescue)
- Gymnocarpium dryopteris (Oak Fern)
- Maianthemum dilitatum (May Lily)
- Smilacina stellata (Starry Solomonseal)
- Tiarella trifoliata (Foam flower)*
- Vancouveria hexandra (Inside out Flower)*

WOODYSHRUB-TREESEED*ROOTPROPAGULES-

- Alnus sinuata (Sitka Alder)
- Rubus ursinus (Trailing Blackberry)
- Saliz scouleriana (Willow)

HARDWOOD & ROOT CUTTINGS

Collected & Propagated ON SITE

- Alnus sinuata (Sitka Alder)
- Cornus stolonifera (Red Osier Dogwood)
- Oplopanax horridum (Devils' Club)
- Populus trichocarpa (Black Cottonwood)
- Rubus spectabilis (Salmonberry)
- Salix scouleriana (Willow)
- Sambucus racemosa (Red Elderberry)
- Spiraea douglasii (Douglas' Spiraea)

HARDWOOD CUTTINGS Collected ON SITE/ Propagated OFF SITE

- Vacinnium alaskense (Alaska Huckleberry)
- Vacinnium ovalifolia (Oval Leaf Huckleberry)

WOODY PLANT SEED Collected ON SITE/ Propagated OFF SITE

- Acer circinatum (Vine Maple)
- Alnus sinuata (Sitka Alder)
- Rhododendron macrophyllum (Rhododendron)
- Sorbus sitchensis (Sitka Mountain Ash)
- Vacinnium alaskense (Alaska Huckleberry)
- Vacinnium ovalifolia (Oval Leaf Huckleberry)

Collected & Seeded ON SITE

- Alnus sinuata (Sitka Alder)
- Spiraea douglasii (Douglas' spiraea)

HERBACEOUS PLANT SEED

Collected & Seeded ON SITE:

- Anaphalis margaritacea (Pearly Everlasting)
- Aruncus sylvester (Goatsbeard)
- Carex martensii & sps. (Martins' Sedge)
- Elymus glauca (Blue Wildrye)
- Epilobium angustifolium (Fireweed)
- Festuca occidentalis (Western Fescue)
- Geum macrophyllum (Avens)
- Glyceria occidentalis (Western Manna Grass)
- Juncus sps. (Rush)
- Lupinus albicaulis (Sickle Keeled Lupine)
- Scirpus microcarpus (Bulrush)
- Smilacina stellata (Starry Solomomseal)
- Xerophyllum tenax (Beargrass)

7.0 GLOSSARY OF PRESENTED WORDS/CONCEPTS

broad-leaf evergreen plants that retain their leaves year round and possess large leaves

collection radius area surrounding a restoration site that provides seeds and transplants that are genetically similar to plants within the work area

crown portion of a plant at the juncture of the root and stem or trunk

dictoyledon one of the two sub-classes of angiospermous plants that produce seeds with two seed leaves on catyledars

diurnal showing a periodic alteration of condition with day and night

dripline area on the ground directly underneath the outermost branch tips of a tree or shrub; generally where water would drip, it is commonly associated with the outside edge of a plant's root zone

friable easily crumbled or reduced to powder

frost heave a condition that results from the flow of water through soil to a freezing point where layers of ice are formed; this condition can thrust germinating seedlings and plants out of the soil

harden-off the process of adapting a plant that has been grown in a greenhouse, indoors or under protective cover to full outdoor exposure

heel-in to store plant material in the open ground; stems, cuttings or plants are placed together in an upright or inclined position in a trench which is then filled with soil or mulch and firmed

mass wasting direct downslope movement of soil bodies as a result of gravitational stress

monocotyledon one of two sub-classes of angiospermous plants that produce seeds with a single seed leaf (grasses)

mulch any loose, usually organic material placed over soil or around plants to prevent excess drying, impede weeds, minimize rapid changes in soil temperature, stabilize soil and serve as a soil amendment

needle leaf evergreen an evergreen plant having needle like leaves; a conifer

nitrogen-fixing the act of converting atmospheric nitrogen into a usable soil nutrient, especially in depleted or damaged sites; Alders and Lupines are nitrogen-fixing plants

plantlets small plants, often resulting from the process of root division

plugs a seedling or grouping of plants with a root ball ready for transplanting

reference community an area with similar topography, elevation and plant communities as the restoration site that can be used for comparison when replicating landscape features and plant combinations

rooting hormone a chemical applied to the cut basal portion of a cutting to stimulate root formation

root pruning the removal of a portion of the roots on a plant by passing a cutting blade under the plants, usually around the dripline of the plant

scarification the process of breaking up top soil; the opening of a hard seed coat to water by wearing away a portion of the surface with an abrasive substance

seedbed a soil medium suitable for seed germination

shade cloth a commercially available fabric that inhibits the amount of sunlight to areas over which it is erected

stolon a stem growing along the ground or under the surface which produces roots and new plants at its nodes

tailings the residue of excavation, usually lying in piles downhill from a mine or barrow

transplant shock physical reaction of a plant directly resulting from either the act or result of transplanting; wilting leaves and drooping stems are examples

Table 1. Response of some common weeds to solarization (from Pullman and others, 1984)

Effective control	
Cocklebur	*Xanthium spinosum*
Common chickweed	*Stellaria media*
Field bindweed (seed)	*Convolvulus arvensis*
Henbit	*Lamium amplexicaule*
Jimsonweed	*Datura stramonium*
Lambsquarters	*Chenopodium album*
Miner's lettuce	*Montia perfoliata*
Nettleleaf goosefoot	*Chenopodium morale*
Prickly lettuce	*Lactuca serriola*
Prickly sida	*Sida spinosa*
Shepherd's purse	*Capsella bursa-pastoris*
Tolerable control	
Large crabgrass	*Digitaria sanguinalis*
Purslane	*Portulaca oleracea*
Partial control (more effective if repeated)	
Bermuda grass	*Cynodon dactylon*
Field bindweed (plant)	*Convolvulus arvensis*
Johnsongrass	*Sorghum halepense*
Nutsedge	*Cyperus* spp.
Lovegrass	*Eragrostis* spp.

Table 2. Predictions of seeding success by site characteristics (Miller and Miller, 1978)

Value[1]	Good	Value	Poor
1	Partial Shade	0	Full Sun
1	Sheltered from wind	0	Exposed to wind
2	Summer soil moisture	–2	Dry in summer
1	Humus in soil	0	A horizon gone
1	Slope < 10%	0	Slope > 10%
2	Summer soil surface temp. < 35°C	–2	Summer soil surface temp. > 35°C
1	No evidence of needle ice	–2	Evidence of needle ice

[1]If total values assigned to a site are less than 5, consider a method of revegetation other than seeding.

Table 3. Descriptions of available mulching systems with costs

Summary of Mulches

Mulch	Manufacturer	Description	Advantages	Disadvantages
Curlex	American Excelsior Company	Aspen wood shavings with photodegradable plastic mesh	east to install, promotes seedling survival, decomposes in 2-5 years	heavy netting may decompose unevenly[1] & needs to be removed after 1-5 years
Hi-Velocity Curlex	American Excelsior Company	Aspen wood shavings with black extra heavy-duty plastic netting on both sides	very effective on steep slopes, promotes seedling survival	heavy, black netting is very visible & lasts for years and years
Eromat	Erosion Control Systems	straw blanket with photodegradable netting on one side & sewn on 2" centers	lightweight, sewn together for easier installation, promotes seedling survival	may decompose quickly
Excelsior Blanket	Erosion Control Systems	excelsior blanket (aspen shavings) with photodegadable netting & sewn on 2" centers	promotes seedling survival, may be easier to install than Curlex since it is sewn	
High Impact Excelsior Blanket	Erosion Control Systems	excelsior blanket with photodegradable on both sides and sewn on 2" centers	easy to install since it is sewn together	
Hold/Gro	Erosion Control Systems	green paper strips interwoven with knitted synthetic yarns	lightweight, recommended for seeded areas	bright green color, ravels if holes are cut for plants, netting lasts for years

[1]A new Curlex with white netting which is sensitive to UV and decomposes more quickly (1-2 years) is now available (6/90).

Summary of Mulch Dimensions & Costs[2]

Mulch	Width (ft.)	Length (ft.)	Area Covered (sq. ft.)	Weight (lbs.)	Cost (roll)
Curlex	4	180	720	78	$38.80 per roll
Hi-Velocity Curlex	4	100	400	72	$51.00 per roll
Eromat	7.5	120	900	42	$49.00 plus shipping
Excelsior Blanket	7.5	96	720	68	$40.80 plus shipping
High Impact Excelsior Blanket	7.5	60	450	50	$35.50 plus shipping
DS150 Straw Blanket	6.5	83	540	30	$48.00
S150 Straw Blanket	6.5	83	540	30	$33.00
SC150 Straw Coconut Fiber Blanket	6.5	83	540	30	$69.00
Box of Staples					$28.00/1000

[2]Costs quoted 8/90
Source: Rochefort, 1990: Table 2

THE AUTHOR

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